CHAPTER 4: BIOTIC RESOURCES

4.0 Introduction

This chapter provides an overview of the biotic resources of the region, the San Lorenzo River watershed, and to the degree possible, on District-owned lands. Because most District-owned lands have not yet been biologically surveyed, the description at this level relies on personal observations of District staff and consultants--as well as the findings of other local studies--to identify communities of plants and animals, to estimate habitat conditions, and to assess future needs for biological surveys.

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The District has not yet established measurable baselines of biotic resource quantities, conditions, and locations.

This chapter begins with a brief discussion of biodiversity, and then identifies major plant communities, wildlife habitats, and fisheries. Next, it describes some of the ecosystem functions and natural services provided by these local biotic resources. Finally, the chapter discusses the role of human activities and their impacts to plant communities, wildlife and fisheries habitats, and ecosystem functions.

It should be noted that climate change has the potential to significantly alter fundamental natural processes that biotic resources depend on, such as the carbon cycle and the hydrologic cycle. Thus, the impacts of climate change on biotic resources are likely to be significant at all landscape scales, though the scope and severity of the impacts are as yet not fully known.

4.1 Biodiversity at regional and watershed scales

As discussed in Chapter 2, the Santa Cruz Mountains is defined as a bioregion (Santa Cruz Mountains Biodiversity Council, 2007), which is home to plant communities, such as those of the sandhills, which are found nowhere else in the world. Santa Cruz County, which lies within the Santa Cruz Mountains, is considered an international “hot spot” for biological diversity because of its unique habitats and ecosystems (Dobson, et al. 1997; McGraw, 2004).

The biological diversity of the Santa Cruz Mountains also characterizes the San Lorenzo River watershed, which contains overlapping habitats of terrestrial, aquatic, and marine species, including 55 species of mammals, 33 species of reptiles and amphibians, and more than 200 species of birds. District-owned lands are home to many of these species, including some of the rarest inhabitants of the sandhills communities. The Santa Cruz Mountains support some of California’s rarest plants and animals including fourteen plants listed as State or Federally threatened or endangered (Morgan et al., 2005). Santa Cruz County has been identified as one of the five most important locations in the U.S. for rare and endangered species (Dobson et. al, 1997). Several species are listed as rare, endemic, threatened or endangered under the federal Endangered Species Act (ESA), the California Endangered Species Act (CESA).

4.1.1 The role of natural disturbance in biodiversity

Disturbance refers to any disruption in the environment that leads to a biological response (Pickett and White, 1985 et al., as cited in Benda et al., 1998). Natural disturbances have shaped the region over the millennia to create its unique landforms, giving rise to its assemblage of habitats and species, and remarkable biodiversity. Because natural disturbances are generally patchy, they tend to shape the landscape into a mosaic of different biological communities, in different states of succession. The resulting abundance of habitats and niches creates a landscape that is more resilient to future disturbances.

Natural disturbances such as fire, storms, floods, landslides, erosion, and earthquakes create new environments. For example, after the ancient sea floor was uplifted over time, and the Miocene sand deposits were exposed to weathering, the resulting erosion created the unique sandhills environment. Today's Zayante sand soils, combined with a maritime climate, gave rise to biological communities found nowhere else in the world. This rare geologic formation occurs throughout the San Lorenzo River watershed, east and west of the Ben Lomond fault, and south of the Zayante fault, and in small isolated patches throughout the rest of the watershed.

Adaptations by species to these new environments can increase biological diversity. For example, the Zayante band-winged grasshopper (*Trimerotropis infantilis)* and the Mount Hermon June beetle (*Polyphylla barbata*) endemic to this area, both adapted to the unique conditions of the sandhills environment (McGraw, 2004).

4.1.2 The role of recent human disturbance

Human disturbance, mostly land-use activities over the last 200 years, has created significant, chronic impacts to plant communities, as well as to wildlife and fisheries habitats. As discussed in the last two sections of this chapter, these impacts have also affected the natural processes that are fundamental to ecosystem function. These processes include the hydrologic or water cycle, nutrient cycle, energy cycle, and ecological community succession.

4.2 Major plant communities of the region, the watershed, and District lands

Plant community classifications and descriptions that follow are partly derived from a publication by Robert Holland of the Department of Fish and Game (Holland, 1986).

The District has not yet mapped and analyzed historical and current vegetation, natural and induced succession, current seral stages of the vegetation or sensitivities to pollution and climate change.

Largely dominated by redwood and mixed evergreen forests, the Santa Cruz Mountains host other major plant communities, including oak woodland, riparian woodland, maritime chaparral, and the endemic sandhills and sand parklands plant communities.

4.2.1 Redwood and mixed-redwood forests

This section provides a description of habitat and range, and attributes of the coastal redwood (*Sequoia sempervirens*) community, with an emphasis on the ecosystem functions of old-growth and late successional forests. The section then describes redwood forest conditions within the San Lorenzo River watershed, and on District lands.

4.2.1.a Habitat and range

Redwood forests are limited to the coast ranges of central and northern California, extending minimally into southern Oregon. Redwoods depend on a coastal maritime climate often with high winter rainfall and a summer stratus layer. When the stratus layer is on the ground, it is called fog, and contributes precipitation to redwoods in the form of fog drip. When the stratus layer is above the tops of the trees, it reduces evapotranspiration levels. The distribution of redwoods is also limited by low temperatures in the winter.

When fog comes in contact with redwoods, it collects on the foliage, condenses, and rolls off the leaves, falling to the ground as fog drip (Haemig, 2003). Dawson (1998) studied heavily fog covered coastal redwood forests of N. California. He found that in summer, when fog was most frequent, 19% of the water within the redwood trees, and 66% of the water within the understory plants came from fog after it had dripped from tree foliage into the soil. Thus, he demonstrated that the trees significantly influence the magnitude of fog water input to the ecosystem. When a redwood forest is cut down, the remaining vegetative community receives less water and summer streamflows within the area are reduced, because of the reduction in fog drip (Haemig, 2003). Open areas without forest cover are also subject to more intense sunlight, which dries out the forest floor.

4.2.1.b Attributes

Haemig (2003) provides a literature review documenting some of the unusual attributes of the coastal redwood:

> According to Sillett and Bailey (2003), large redwood trees are among the most structually complex trees on earth, with individual crowns composed of multiple, reiterated trunks rising from other trunks and branches . . . indistinguishable from free-standing trees except for their origins within the crown of a larger tree (see also Sillett, 1999). For example, Sillet and Van Pelt (2000) studied a single old-growth redwood tree in Redwood National Park and found that its crown had 148 resprouted trunks arising from the main trunk, other trunks, or branches. Five of the resprouted trunks had a basal diameter of over one meter, and the largest resprouted trunk was over 40 meters tall. These researchers concluded that the crown of this redwood could itself be considered a forest.

Each year, redwoods shed some of their foliage. Some foliage falls to the ground, and some foliage accumulates on large branches of the tree, decomposing there into soil known as *canopy soil*. Seeds of plants and spores of fungi colonize canopy soil, eventually creating a plant community high in the canopy of redwood trees (Sawyer et al., 2000). Plants that grow on trees rather than on the ground are called *epiphytes*. Redwood trees often support sizable communities of epiphytes because their large size, great height and complex architecture make them excellent structures for soil and plants to colonize. The complex treetop communities of plants and animals that live in the redwood canopy take many hundreds of years to develop. Some redwood forests, logged in the past 200 years, now contain trees that are big enough to start collecting canopy soils and epiphytes. However, these redwoods are usually felled as timber before their canopy communities become fully developed.

4.2.1.c Redwood and mixed redwood forest of the San Lorenzo River watershed

The plant communities with the highest representation in the San Lorenzo River watershed are redwood and mixed evergreen forests. These communities cover approximately 66,968 acres, or about 74.9% of the San Lorenzo River watershed's land area (San Lorenzo Valley Water District, 1985; Singer, 1979).

Most of the original old-growth redwood (*Sequoia sempervirens*) and Douglas fir (*Psuedotsuga menziesii*) forests in the San Lorenzo River watershed were clear-cut and burned during the late 1800s and early 1900s. Some areas, such as Big Basin and Henry Cowell State Parks, still retain old-growth forests. Patches of old-growth forests and residual old-growth trees are scattered throughout the watershed. However, most of the redwood forest in the San Lorenzo River watershed consists of second-growth or third-growth stands, which sprouted from stumps of the original forest.

Other trees found in local redwood and mixed redwood forests include Douglas fir, tan oak (*Lithocarpus densiflorus*), madrone (*Arbutus menziessi*), and California bay (*Umbellularia californica).* Douglas-fir is a very important component of redwood forests in the Santa Cruz Mountains. It provides the major source of snags and large down logs, and in second-growth forests Douglas fir acquires old-growth characteristics much faster than redwood. Also found, especially in riparian areas, are white alder (*Alnus rhombifolia*), as well as big-leaf maple (*Acer macrophyllum*). Pacific wax myrtle (*Myrica californica*) occurs in redwood forests nearer the coast. Common shrubs include huckleberry (*Vaccinium ovatum*), western azalea (*Rhododendron occidentale*), and California hazelnut (*Corylus cornuta* var. californica). Ferns growing in the redwood forest include western sword fern (*Polystichum munitum*) and giant chain fern (*Woodwardia fimbriata*). Ground covers include redwood sorrel (*Oxalis oregana*), wild ginger (*Asarum caudatum*), redwood violet (*Viola sempervirens*), trillium (*Trillium ovatum*), star lily (*Zigadenus fremontii*) and Pacific Coast iris (*Iris douglasiana).* Fall and winter rains deliver hundreds of kinds of fungi.

At higher elevations, redwoods transition into more drought-tolerant species of the mixed evergreen and chaparral plant communities, which also commonly dominate the drier south-facing slopes.

4.2.1.d Redwood and mixed redwood forest on District land

Redwood and mixed redwood forest covers most of the District's land around its surface water sources, as pictured in Figure 4.1. Some of the District-owned watershed lands contain late successional stands, along with other species noted for the larger watershed. Figure 4.2 shows the undisturbed forest floor on District land, carpeted with redwood sorrel.

Figure 4.1. Typical mixed redwood forest on District-owned watershed land

Herbert 2006

View looking southwest from District-owned property near Malosky Creek, showing typical second-growth redwoods and Douglas fir, interspersed with madrones and native chaparral shrubs.

Figure 4.2. Undisturbed forest floor in a mature forest on District watershed land

Herbert 2006

This forested slope near one of the District's surface water intakes is carpeted with the native redwood sorrel (*Oxalis oregana*).

4.2.2 Black oak woodland plant communities

The deciduous California black oak *(Quercus kelloggii.)* is often found along with interior live oak and canyon live oak in the Santa Cruz Mountains. Preferring hot, dry summers, black oaks are found on ridgetops and in other well-drained areas of the San Lorenzo River watershed, such as in Upper Zayante.

In general, stands of California black oak in the San Lorenzo River watershed are even-aged, originating from some past disturbance such as fire or logging. In the absence of disturbance, black oaks can be overtopped by conifers and eventually replaced because of inherent shade intolerance.

4.2.3 Mixed evergreen forest plant communities

Mixed evergreen forest plant communities occur in the Santa Cruz Mountains, the San Lorenzo River watershed, and on District land. Frequently adjacent to redwood forests, mixed evergreen forests occupy drier and more inland areas, such as Quail Hollow and Zayante. Common trees include Douglas fir (*Pseudotsuga menziesii*), interior live oak (*Quercus wislizenii*), tan oak

(*Lithocarpus densiflora*), madrone (*Arbutus menziesii*), California bay (*Umbellularia californica)*, California buckeye (*Aesculus californica*), and Santa Cruz Mountain oak (*Quercus pavrula* var. *shrevei*). Understory plants include ceonothus, coffee berry, hazelnut, ground rose, and poison oak.

4.2.3.a Sudden oak death

An emergent plant disease, sudden oak death has killed hundreds of thousands of tan oaks and oaks and is dramatically changing the composition of our forests and woodlands. Sudden oak death (SOD) is caused by an invasive non-native water mold, *Phytophthora ramorum*, that first appeared in Marin County in 1995. It subsequently has spread to nearby counties, appearing in Santa Cruz County in 2000. It is now found in all coastal and East Bay Area counties from Humboldt County south to Monterey County, and also in Curry County, Oregon (COMTF 2008).

P. ramorum is the causal agent for two different, but related, diseases – SOD, which is fatal to the tree, and foliar/twig disease which is also known as Ramorum leaf blight and/or Ramorum shoot dieback. SOD affects tan oaks (*Lithocarpus densiflorus*) and most "true" oaks such as coast live oak (*Quercus agrifolia*), interior live oak (*Q. wizlizenii*), Shreve's oak (*Q. parvula* var. *shrevei*), canyon live oak (*Q. chrysolepis*), and black oak (*Q. kelloggii*). Foliar/twig disease is a less virulent disease that affects many other native plant species including coast redwood (*Sequoia sempervirens*), California bay (*Umbellularia californica)*, Douglas-fir (*Pseudotsuga menziesii*), madrone (*Arbutus menziesii)*, bigleaf maple (*Acer macrophyllum*), and a number of native shrubs. *Phytophthora* spores can be found in soil, water, and plant material. The pathogen prefers moist conditions with the risk of movement and spread being greatest during the rainy season. California bay trees are easily infected, and are, for some unknown reason, one of the hosts most effective in spreading the disease. There is no cure for SOD or foliar/twig disease, but the foliar/twig form is not known to be fatal. (COMTF 2008, Davidson et al. 2003).

Tan oaks are especially susceptible to SOD, and once infected, will usually die within 2 – 6 years (Swiecki and Bernhardt 2007). Infected trees can be identified through the following symptoms, not all of which are always present:

1. Sudden browning of all leaves (leaves go from green to brown in 2 – 4 weeks)
2. "Bleeding" spots of dark red to black sticky sap on trunk
3. Frass (looks like sawdust) on the trunk or at base of tree, derived from beetle bore holes in the trunk. Bark beetles are attracted to dying trees, whatever the cause.
4. Black fungi fruiting caps, like small black balls, present on the bark. These are *Hydroxylon* fungi which attack dying trees, whatever the cause.

A two-year study conducted at Point Reyes National Seashore (Moritz et al. 2008), where the first signs of SOD were observed in 2004, reported the following preliminary findings:

- By 2007, 63% of redwood-tan oak stands, 45% of California bay – coast live oak stands, and 24% of Douglas-fir stands were infected by *P. ramorum*.
- Tan oak mortality was greater than 95%, by basal area, in several plots and may have reached 100% in some locales.
- In redwood plots tan oak accounted for an average of one-third of tree species richness and one fifth of total woody species richness. If it were to be eventually eliminated by SOD, the species richness of redwood forests would be severely reduced.
- Mean total fuel loading was greater in diseased redwood plots than in healthy redwood plots.

Tan oaks are the most abundant understory tree in the watershed's redwood forests, and their demise will have ecosystem-changing impacts. They are a prolific producer of acorns which are a major wildlife food item, being utilized by squirrels, chipmunks, deer, woodrats, quail, and band-tailed pigeons, to name a few. These animals and the predators that feed on these animals will be affected, and the ecosystem functions performed by these animals will be impaired. For example, if squirrel numbers are reduced, the dispersal of mycorrhizal fungi may be reduced, this in turn would effect tree growth.

Doug McCreary, Ecologist, U.C. Cooperative Extension's Integrated Hardwood Range Management Program, has pointed out the potentially severe and far-reaching consequences of high levels of oak tree mortality (McCreary, 2001):

> There could be significant impacts to the many wildlife species that are so dependent on coastal oak forests for food and shelter. Deer, turkeys, jays, quail, squirrels, and acorn woodpeckers are just a few of the many species that rely heavily on acorns as a food source. And there are countless other animals that use oak woodland for breeding or as stopover points during migration. Ecological processes such as nutrient cycling, storage and release of water, and moderation of soil temperatures could also be affected. Of more immediate concern, however, is the greatly increased risk of fire resulting from the addition of large quantities of highly combustible fuels. This risk is particularly serious because so much of the coastal forest contains urban interface areas where homes and businesses are nestled among the trees.

4.2.4 Chaparral plant communities

At higher elevations above the fog line, and on south-facing slopes, the mixed redwood forest often transitions into chaparral plant communities, which occupy the hottest and driest slopes of the Santa Cruz Mountains. Chaparral plants thrive on the south-facing slopes and rocky ridgetops of the San Lorenzo River watershed, including District-owned lands.

Chaparral plants form dense thickets comprised of shrub species that are adapted to little water and to wildfire. Leaves of chaparral plants are often small, thick, light green or grayish, and waxy. Leaves are retained year round on most species, but are dropped in summer by others to conserve moisture.

Toyon (*Heteromeles arbutifolia*), coffeeberry (*Rhamnus californica*), ceanothus (*Ceanothus spp.),* Manzanita (*Arctostaphylos spp*.), chaparral pea (*Pickeringia montana*), sage (*Salvia mellifera*.), coyote bush (*Baccharis pilularis*) and chamise (*Adenostoma fasciculatum*) are all well adapted to these dry conditions. Pine (*Pinus attenuata*), golden chinquapin (*Chrysolepis chrysophylla* var. *minor*), and buckeye (*Aesculus californica*) provide taller cover. Chaparral wildflowers are primarily shrubby species including sticky monkey flower (*Mimulus aurantiacus*), Indian paintbrush (*Castilleja sp.)*, California fuschia (*Zauschneria californica*), bush poppy (*Dendromecon rigida*) and yerba santa (*Eriodictyon californicum*).

4.2.5 Plant communities of the Santa Cruz sandhills

Two uncommon communities have been described within the Santa Cruz sandhills: Northern Maritime Chaparral, which includes silverleaf manzanita (*Arctostaphylos silvicola*), and Maritime Coast Range Ponderosa Pine Forest. These plant communities are known locally as *sand chaparral* and *sand parkland*, respectively (McGraw, 2004). Both of these communities have been documented on the District's Olympia watershed property (Harvey & Stanley Associates, Inc., 1983; McGraw, 2004).

4.2.5.a Sand chaparral

Sand chaparral is dominated by shrubs including buck brush (*Ceanothus cuneatus* var. *cuneatus)*, and silverleaf manzanita, which is endemic to the sandhills. Sand chaparral also contains scattered trees, including short-statured coast live oaks and two species of pine: knobcone (*Pinus attenuata*) and ponderosa (*Pinus ponderosa*). Within the gaps in the shrub and tree canopy, sand chaparral supports numerous herbaceous plants, including several species of Navarettia, everlasting nest-straw, Santa Cruz monkeyflower, and the Ben Lomond spineflower (*Chorizanthe pungens var. hartwegiana*), which is also endemic to the sandhills.

4.2.5.b Sand parkland

Sand parkland is an extraordinarily rare community, occurring on fewer than 200 acres in the world. Sand parkland is characterized by a sparse canopy of ponderosa pines surrounded by a diverse assemblage of subshrubs and herbaceous plants. Sand parkland contains the highest diversity and abundance of rare and unique plant species, including the three endemic to the sandhills: the Ben Lomond spineflower (*Chorizanthe pungens ssp. Hartwegiana*), Santa Cruz wallflower (*Erysimum teretifolium*), and Ben Lomond buckwheat (*Eriogonum nudum var. decurrens*).

4.2.5.c Habitat

The permeable, sandy soils of the sandhills limit water availability to vegetation. Evaporation rates are high, and temperatures are extreme, due to the open ecosystem and reflective soil. The origin of the sandhills at the bottom of a Miocene sea is a factor that limits plant growth. Natural compaction in most soils is in the 75-85% range, which permits roots to go deep and support healthy plant growth. However the sea floor was heavily compacted by the weight of billions of gallons of water, resulting in natural compaction that exceeds 100% in some locations. Few species are able to thrive in such heavily compacted sand, but Ponderosa pine and silver-leafed manzanita fare better than most. The veneer of weathered soil that overlies this parent material is so thin it gives rise to an array of unique annuals and perennials (Schlettler, 2008). The sandy soil lacks organic matter and nutrients, and its white color magnifies the temperature of the summer sun (California Native Plant Society, 2007). Plants and animals of the sandhills communities have developed unique adaptations to these features. Many of the plants thrive on soil that is too poor in nutrients for commoner species. Most tend to be annual or to be summer-dormant, growing only in the cooler and moister seasons.

4.2.5.d Range

Located predominantly on steep ridges within the Santa Cruz sandhills, the sandhills community historically encompassed approximately 6,000 acres. Less than 4,000 acres of this rare ecosystem remains in the world, restricted to these sand outcroppings (McGraw, 2004). Of the remaining acreage, only 2,500 acres are of high habitat quality, and only approximately 600 acres are of good habitat quality (McGraw, 2004). Only about 200 acres remains of the rare sand parkland community (McGraw, 2004).

At the ground's surface, sandy soils that form sandhills and sand parkland are found in patchy "islands" of various sizes scattered throughout the Santa Cruz Mountains. Typical sandhills and sand parkland communities can be found in Quail Hollow Ranch County Park, in the District's Olympia watershed land, surrounding existing and abandoned sand quarries, in Scotts Valley, Mt. Hermon, and in patches elsewhere.

Figures 4.3 and 4.4 show plant communities of the sandhills intersecting with riparian woodland on District-owned lands, and interspersed with invasive exotic species including acacia, eucalyptus and French broom.

Figure 4.3 The rare sandhills community at the District-owned Olympia watershed lands

Herbert 2006

Revegetation in the old Ferrari quarry on the District's Olympia Watershed property occurred spontaneously after the closure of the quarry. Ponderosa and knobcone pines, silver-leaf manzanita, and many rare and endangered plants and animals are found in this area, interspersed with invasive exotic species. Rare species have been documented on District lands (McGraw, 2004).

Figure 4.4 Chaparral and riparian woodland habitat at the District-owned Olympia watershed lands

Herbert 2006

Sand chaparral meets riparian woodland near the old Olympia quarry. Here, native golden fleece (*Ericameria ericoides*) is going to seed in late fall. Black cottonwoods (*Populus trichocarpa*) along the creek in the background have dropped their leaves.

4.2.5.e Special status plant species of the sandhills

The sandhills support a unique flora. Many of the plant species composing the community are disjunct coastal species, isolated in the sandhills miles from the coast. Many of these disjunct coastal species even exert different morphologies from their coastal counterparts. The sandhills also contain forms of species that are common elsewhere in the state, but have strikingly different forms or habits than those found elsewhere. Examples are California poppy *(Eschsholzia californica)*, ponderosa pine *(Pinus ponderosa),* and tidy tips *(Layia platyglossa)*.

Both sand chaparral and sand parklands are home to many threatened and endangered plants. Table 4.1 lists these special status species.

Table 4.1 Special status plant species of the sandhills and sand parkland habitats

Common name	Species name	Status
Silver leaf manzanita	*Arctostaphylos silvicola*	Endemic to sandhills
Santa Cruz cypress	*Cupressus abramsiana*	State endangered; Federally endangered
Santa Cruz monkey flower	*Mimulus rattanii decurtatus*	Rare; endemic to California
Ben Lomond buckwheat	*Eriogonum nudum var. decurrens*	Endemic to sandhills
Ben Lomond wallflower	*Erysimum teretifolium*	Endemic to sandhills; Federally protected
Ben Lomond spine flower	*Chorizanthe pungens ssp. hartwegiana*	Endemic to sandhills; Federally protected

Source: McGraw, 2004.

4.2.5.f Loss of sand chaparral and sand parkland communities

Most losses of sand chaparral and sand parkland have occurred due to open pit mining in the watershed and on District-owned lands (before the District acquired these lands). Houses and roads have also been built upon the rare and fragile ecological community.

Sand chaparral and sand parkland are very fragile, and extremely susceptible to disturbance. Disturbance from off-road vehicles, mountain biking, horseback riding and even foot traffic can severely damage and alter the vegetative community. All of these activities occur on the District-owned lands. For more information about the impacts of recreational uses, refer to Chapter 6. In addition, invasive plant species such as French broom and acacia are present on the District-owned Olympia watershed lands, where they compete with endangered species for limited habitat. These areas are extremely susceptible to adverse affects of erosion and concentrated runoff, as is discussed in Chapter 3, Hydrology, Geomorphology, and Water Quality.

4.2.6 Riparian woodland plant communities

The riparian woodland plant communities generally form a linear corridor along both sides of a stream (lotic aquatic environment), or surrounding a lagoon or lake (lentic aquatic environment). Riparian vegetation may be defined as "any extra-aquatic vegetation that directly influences the stream environment by providing shade, large debris, or fine litter" (Meehan et al., 1977). Thus, trees growing above the floodplain on terraces and hill slopes are considered riparian, if they influence shading and/or may be a source of energy and large woody material to the stream.

4.2.6.a Riparian woodland in the San Lorenzo River watershed

Several local riparian forest types may combine to form the riparian corridor, and they are commonly interspersed with other woody and shrubby species, including redwood trees. Native deciduous trees common to the riparian corridor in the San Lorenzo River watershed may include species of willow (*Salix spp.*), alder (*Alnus spp.*), black cottonwood (*Populus balsamifera* subspecies *trichocarpa*), California sycamore (*Plantus racemosa*), big leaf maple (*Acer macrophyllum*), creek dogwood (*Cornus sericea*), and California box elder (*Acer negundo*).

4.2.6.b Riparian woodland on District-owned land

Figure 4.5 depicts riparian woodland above the District's Quail Hollow Well.

Figure 4.5 Riparian woodland in Quail Hollow above the District's well.

Herbert 2006

Black cottonwood *(Populus balsamifera ssp. Tricocarpa)* and Douglas fir (*Pseudotsuga menziessi*) shade the creek between the District's two active Quail Hollow wells.

4.2.7 Grassland plant communities

Much of the region's coastal prairie has been destroyed due to agriculture and development, The remaining areas have been invaded by exotic weeds such as annual ryegrass (*Lolium multiflorum*), wild oats (*Avena fatua*), annual fescues (*Vulpia bromoides*), bromes (esp. *Bromus diandrus*), velvet grass (*Holcus lanatus*), and thistles (esp. *Carduus pycnocephalus*). The remaining, in tact areas of coastal prairie are recognized by the presence of California oatgrass (*Danthonia californica*) and/or wildflowers, such as native bulbs (*Brodiaea* and *Triteleia* species), lupines (*Lupinus nanus*), self-heal (*Prunellus vulgaris*), and many others. The best areas to view coastal prairie are at UCSC's upper campus (Marshall Meadows), State Parks' Gray Whale Ranch, and just north of Año Nuevo along the coast south of Franklin Point.

4.2.8 Other endemic, rare, and endangered plant species of the region

The coast rock cress (*Arabis blepharophylla*) occurs on rocky coastal bluffs, bare granitic soils, and open grassy slopes on the coastal side of the Santa Cruz Mountains. Thomas (1961) found coast rock cress near Boulder Creek. The San Francisco wallflower (*Erysimum franciscanum var. franciscanum*) was found near Forest Park by the California Native Plant Society (San Lorenzo Valley Water District, 1985).

Table 4.2 lists species on the federal Endangered Species List, known to inhabit the San Lorenzo River watershed or elsewhere in the county.

Table 4.2. Listed threatened and endangered species in Santa Cruz County

Common name	Latin name	Status*
Plants		
Ben Lomond spineflower	*Chorizanthe pungens* var. *hartwegiana*	FE
Ben Lomond wallflower (also called Santa Cruz wallflower)	*Erysimum teretifolium*	FE, SE
Monterey spineflower	*Chorizanthe pungens* var. *pungens*	FT
Robust spineflower	*Chorizanthe robusta* var. *robusta*	FE
Santa Cruz cypress	*Cupressus abramsiana*	FE, SE
Santa Cruz tarplant	*Holocarpha macradenia*	
Scotts Valley polygonum	*Polygonum hickmanii*	FE, SCE
Scotts Valley spineflower	*Chorizanthe robusta* .var. *hartwegii*	FE
Tidestrom's lupine (clover lupine)	*Lupinus tidestromii*	SE
White-rayed pentachaeta	*Pentachaeta bellidiflora*	FE, SE
Invertebrates		
Smith's blue butterfly	*Euphilotes enoptes smithi*	FE
Mt. Herman June beetle	*Polyphylla barbata*	FE
Ohlone tiger beetle	*Cicindela ohlone*	FE
Zayante band-winged grasshopper	*Trimerotropis infantilis*	FE
Fish		
Coho salmon-central California ESU	*Oncorhynchus kisutch irideus*	FE, SE
Steelhead-central California ESU	*Oncorhynchus mykiss irideus*	FT
Tidewater goby	*Eucyclogobius newberryi*	FE
Amphibians		
Santa Cruz long-toed salamander	*Ambystoma macrodactylum corceum*	FE, SE
California tiger salamander	*Ambystoma californiense*	FT
California red-legged frog	*Rana aurora draytonii*	FT
Reptiles		
San Francisco garter snake	*Thamnophis sirtalis tetraenia*	FE, SE
Birds		
Western snowy plover	*Charadrius alexandrinus nivosus*	FT
Bank swallow	*Riparia riparia*	ST
Marbled murrelet	*Brachyramphus marmoratus*	FT, SE
California black rail	*Laterallus jamaicensis coturniculus*	ST
American peregrine falcon	*Falco peregrinus anatum*	SE

Sources: Morgan and the Santa Cruz Flora Committee, CNPS, 2005..
California Department of Fish and Game, 2008
FE= Federally listed, Endangered; FT=Federally listed, Threatened;
SE= State-listed Endangered; ST=State-listed, Threatened
SCE= State-listed, candidate Endangered

If the above list included species that historically inhabited the watershed, it would be considerably longer. While no bat species are listed under the Endangered Species Act, many species of bats are considered a species of special concern. Table 4.3 lists bat species that have been observed in the San Lorenzo River watershed.

Table 4.3. Status of bat species observed in the San Lorenzo River watershed

Family VESPERTILIONIDAE (Plain-nosed or mouse-eared bats)		
Common name	**Latin name**	**Status**
Little brown myotis	*Myotis lucifugus*	
Yuma myotis	*Myotis yumanensis*	**FSC/CSC/BLMS**
Long-eared myotis	*Myotis evotis*	**FSC/BLMS**
Fringed myotis	*Myotis thysanodes*	**FSC/BLMS/WBWG**
Long-legged myotis	*Myotis volans*	**FSC/BLMS/WBWG**
California myotis	*Myotis californicus*	
Silver-haired bat	*Lasionycteris noctivagans*	
Big brown bat	*Eptesicus fuscus*	
Western red bat	*Lasiurus blossevillii*	**FSS/WBWG**
Hoary bat	*Lasiurus cinereus*	
Townsend's big-eared bat	*Corynorhinus townsendii*	**FSC/CSC/FSS/BLMS/WBWG**
Pallid bat	*Antrozous pallidus*	**CSC/FSS/BLMS/WBWG**
Family MOLOSSIDAE (Free-tailed bats)		
Mexican free-tailed bat	*Tadarida brasiliensis*	

FSC = Federal Special Concern species (former Category 2 candidates for ESA listing)
CSC = California Department of Fish and Game's California Special Concern species
FSS = Forest Service Sensitive species
BLMS = Bureau of Land Management Sensitive species
WBWG = Western Bat Working Group High Priority species

Source: Table adapted from table provided by Paul A. Heady, Biologist and California Department of Fish and Game.

4.3 Wildlife species of the region, the watershed, and District lands

This section describes the wildlife species of the Santa Cruz Mountains, which are also known to occur in the San Lorenzo River watershed, and probably occur on District lands, although District lands have not been surveyed. Species are grouped by the plant communities on which they depend, including redwood forests, old-growth and late successional redwood forests, riparian woodland, and chaparral.

The District has not conducted a wildlife habitat analysis, using the California Wildlife Habitat Relationships System, on its watershed lands.

4.3.1 Wildlife species of redwood and mixed redwood forest communities

Native understory plants, such as blackberry, huckleberry, and California hazelnut, with abundant fruit and seeds, provide forage for wildlife. The natural cavities in old-growth redwood trees provide nest sites for birds, cover for small mammals, and roosting areas for bats. The cool, damp microclimate of redwoods attracts more amphibians than the drier mixed evergreen forest.

The City of Santa Cruz (Swanson Hydrology & Geomorphology, 2001) lists some of the wildlife species supported by mixed redwood throughout their 3,880 acre holdings in the San Lorenzo River watershed:

> Representative amphibians that inhabit redwood forests include rough-skinned newt (*Taricha granulosa*), ensatina (*Ensatina eschscholtzii*), Pacific giant salamander (*Dicamptodon ensatus*) and arboreal salamander. Typical year-round resident birds include Steller's jay (*Cyanocitta stelleri*), common raven (*Corvus corax*), northern saw-whet owl (*Aegolius acadius*), pileated woodpecker (*Dryocopus pileatus*), hairy woodpecker (*Picoides villosus*), pygmy nuthatch (*Sitta pygmaea*), brown creeper (*Certhia americana*), winter wren (*Troglodytes troglodytes*), chestnutbacked chickadee, golden-crowned kinglet (*Regulus satrapa*), dark-eyed junco (*Junco hyemalis*) and purple finch. Usual summer residents include, Pacific-slope flycatcher, hermit thrush and hermit warbler (*Dendroica occidentalis*), while winter residents consist of ruby-crowned kinglet, varied thrush (*Ixorues naevius*) and Townsend's warblers. Representative redwood forest mammals include Trowbridge's shrew (*Sorex trowbridgii*), shrew-mole (*Neurotrichus gibbsii*), broad-footed mole, long-eared myotis (*Myotis evotis*), western gray squirrel, raccoon and black-tailed deer.

Steller's jay (*Cyanocitta stelleri*) and Swainson's thrush (*Catharus ustulatus*) are more abundant on the edges of redwood forests than the interiors, while the varied thrush (*Ixorcus naevius)*, brown creeper (*Certhia americana*), winter wren (*Troglodytes troglodytes*), and Pacific-slope flycatcher (*Empidonax difficilis*) are more abundant in the interior of redwood forests than the edges (Brand and George, 2001). Predation of bird nests appears to be greater on the edges of redwood forests than the interior. In a study using artificial nests with quail eggs, Brand and George (2000) found that the chances of the nest being found and eaten by a predator decreased as the distance from the forest edge increased, up to a distance of 115 meters from the forest edge.

4.3.2 Wildlife species of old-growth and late-successional redwood forest communities

Only 4% of the original ancient coast redwood forest remains. The other 96% has been logged within the last 200 years (Hunter and Bond, 2001). Scattered old-growth redwood trees that were not cut during the original large-scale logging are called "residual trees" by wildlife managers. These trees provide important habitat structures that certain species of wildlife need and which younger second-growth trees don't provide. According to Hunter and Bond (2001):

> These individual large residual trees or small stands of residual trees are often the only remaining complex structural elements in a matrix of younger forest. As such, they provide the best foraging, resting, and breeding sites for wildlife normally associated with older forests.

Old-growth forests support abundant biodiversity. They provide breeding habitat necessary for such bird species as spotted owl, pileated woodpecker, the federally listed marbled murrelet, the federally listed northern spotted owl, golden-crowned kinglet, hermit warbler, Vaux's swift, and purple martin.

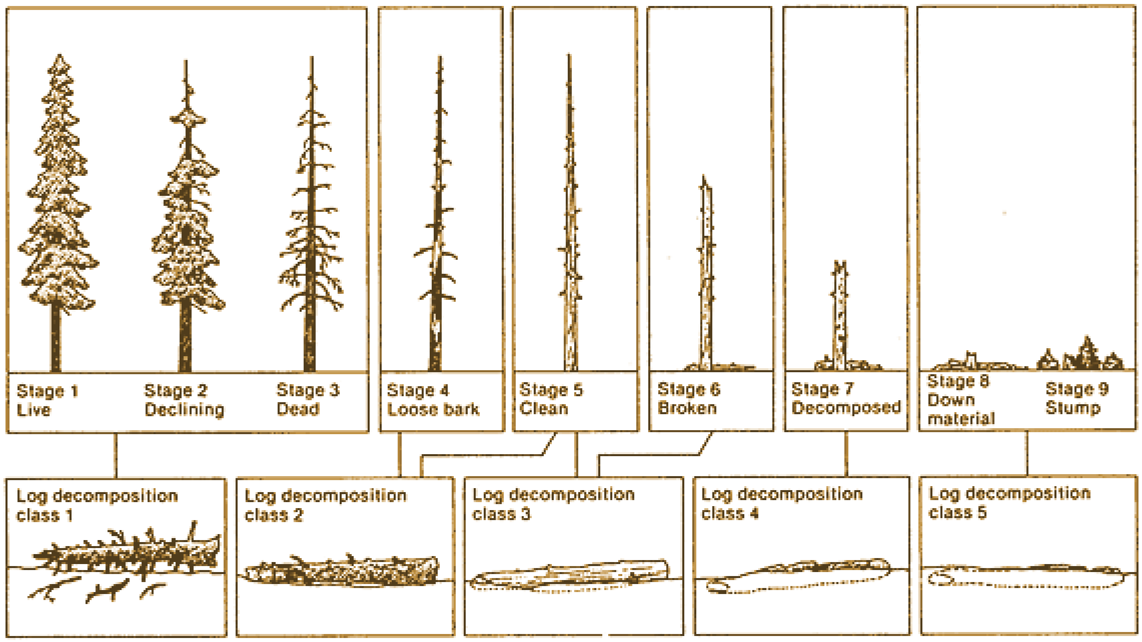
Animals including beetles, crickets, earthworms, millipedes, mollusks, arthropods and amphibians colonize the soils and plant communities of the redwood canopy (Sawyer et al., 2000; Sillett and Bailey, 2003). One noteworthy animal is the clouded salamander (*Aneides* *vagrans*), the only salamander species outside the New World tropics known to live entirely in tree canopies (Cooperrider et al., 2000).

Many species of birds nest high in the canopy of old-growth redwood trees. These include peregrine falcons (*Falco peregrinus*), bald eagles (*Haliaeetus leucocepahlus*), marbled murrelets (*Brachyramphus marmoratus*), northern spotted owls (*Strix occidentalis caurina*) and the fisher (*Martes pennanti*) (Binford et al., 1975; Hunter and Bond, 2001; Cooperrider et al., 2000). In addition, Vaux's swift (*Chaetura vauxi*) nests and roosts inside old, hollow redwood trees (Sterling and Paton, 1996). The California condor (*Gymnogyps californianus*) possibly nested in the redwood canopy, as well. Two hundred years ago, this giant bird was common along the coast of northern California, but was extirpated there before ornithologists could study it. In the Sierra Nevada, where the condor survived much longer, ornithologists found it nesting in cavities of the giant sequoia (*Sequoiadendron giganteum*), a tree related to the coast redwood (Koford 1953; Snyder et al. 1986).

Many birds and some mammals nest or den in cavities or spaces under bark of snags, as illustrated in Figure 4.6. Birds nest in primary or secondary cavities. Primary cavity dwellers, such as woodpeckers, excavate their own holes. Secondary cavity dwellers use abandoned holes or drive off primary cavity dwellers to use their nests. The space behind lifted bark also provides rookeries (nesting habitat) for such birds as the brown creeper (*Certhia americana*), as well as roosting and nesting habitats for bats. Larger owls and birds of prey are dependent upon platforms atop snags or live trees for nesting. Reductions in snags will reduce populations of cavity dwelling species.

Many birds and mammals depend upon snags as food sources. Woodpeckers pick insects off all parts of dead and dying trees. Acorn woodpeckers, found throughout the San Lorenzo River watershed, use snags and sometimes live trees as *granaries* (food storage banks) to store acorns and attract insects to feed upon later. Snags host many different fungi, which are food sources for some insects and small mammals. The increased insect densities associated with snags provide food for bats and many bird species.

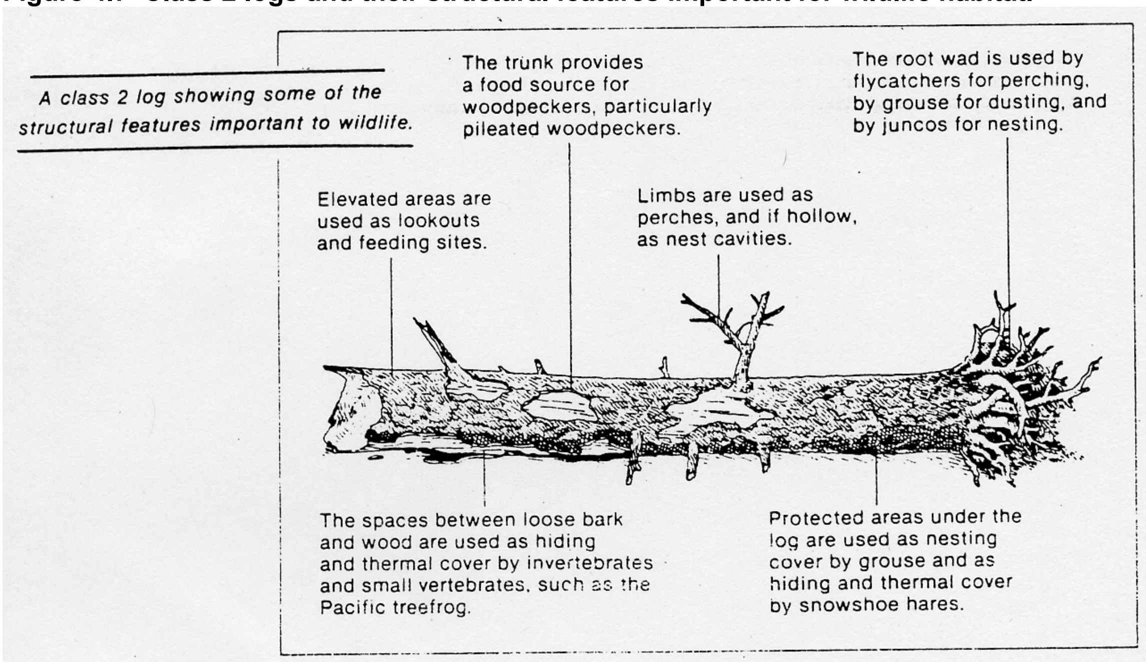
Figure 4.6 Stages of standing snags, and classes of decomposition of downed logs.



Source: Bull, et al., 1997.

Downed logs on the forest floor also provide valuable habitat for wildlife. Figure 4.7 depicts the important structural features for habitat of Class 2 logs. Class 1 is more structurally sound, upright and generally has more intact branches and bark than more decayed classes. As the log progresses through the stages of decay, its structural integrity is slowly lost, and its habitat type becomes more suitable to smaller animals. As it decays further, its habitat type becomes more suitable to plants and fungus than to animals. Eventually, the log decomposes into the duff layer of the soil. The more decayed logs of Class 3 and Class 4 have 1.5 more nitrogen than live wood (Maser et al., 1979).

Figure 4.7 Class 2 logs and their structural features important for wildlife habitat.



Source: Maser et al., 1979.

Large downed logs provide habitat for many wildlife species. Some species rely on downed logs as their primary habitat. Logs of at least 15 inches in diameter are particularly important to species such as the pileated woodpecker (Bull et al., 1997). In the United States, more than 1,200 wildlife species rely on dead, dying, or hollow trees, and logs for dens, roost areas, and feeding sites (Maser et al., 1979).

4.3.3 Wildlife species of riparian plant communities

Riparian plant communities support an especially high degree of biological productivity. The wide variety of plant species provides a large food base for wildlife. Riparian vegetation is generally dense, providing cover from predation. The dense, lush vegetation and presence of water in riparian habitat also creates a mild microclimate. Stratified vegetation within the riparian zone provides various ecological niches. Most terrestrial wildlife species use riparian zones when available, and some reside only within riparian zones. Riparian habitat is an important breeding habitat for many species.

Throughout the state of California, the riparian zone provides one of the most important habitats for wildlife. The California Department of Fish and Game stated that riparian habitat provides living conditions for a greater variety of wildlife than any other habitat type (San Lorenzo Valley Water District, 1985). Riparian zones support the most diverse and abundant avifauna in California (Small et al., 1998).

The most direct link between terrestrial and aquatic ecosystems occurs in the riparian zone, and consequently, the health of aquatic ecosystems is inextricably tied to the integrity of the riparian zone (Spence et al., 1996). Riparian zones are linear, and are used by wildlife as corridors, which are important in connecting fragmented habitats created by rural land disturbance.

4.3.4 Wildlife species of chaparral plant communities

Denser stands of chaparral plants are especially suited to secretive wildlife species that seek extensive cover (Swanson Hydrology & Geomorphology, 2001). More open areas provide look-outs for predator species, and less cover for prey. More structural complexity is provided in areas where chaparral is interspersed with trees. These areas provide the most habitat value.

A wide variety of reptiles make use of chaparral plant communities. Prey populations of rodents and invertebrates provide foraging resources, while rock outcrops and the abundance of low-growing shrubs offer excellent cover, sunning, and territorial display sites (Swanson Hydrology & Geomorphology, 2001). Common wildlife expected to inhabit the chaparral habitats include western fence lizard (*Sceloporus occidentalis*), California whipsnake (*Masticophis lateralis*), and western rattlesnake (*Crotalus viridis*). Chaparral supports a limited number of year-round bird species, including wrentit (*Chamaea fasciata*), Bewick's wren (*Thryomanes bewickii*), California towhee (*Pipilo crissalis*), spotted towhee (*P. maculatum*), California thrasher (*Taxostoma redivivum*), and scrub jay (*Aphelocoma coerulescens*). Manzanitas are an important nectar source for hummingbirds. Summer resident birds may include Anna's hummingbird (*Calypte anna*), Allen's hummingbird (*Selasphorus sasin*), and blue-gray gnatcatcher (*Polioptila caerulea*). Winter residents may include fox sparrow (*Passerella iliaca*), white-crowned sparrow (*Zonotrichia leucophrys*) and golden-crowned sparrow (*Zonotrichia atricapilla*).

Mammal species that prefer dense chaparral may include brush rabbit (*Sylvilagus bachmani*), deer mouse (*Peromyscus maniculatus*) and brush mouse (*Peromyscus boylii*). Predatory species that forage in dense chaparral include bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), and spotted skunk (*Spilogale putorius*). Coyotes (*Canis latrans*) forage in open, disturbed areas of chaparral.

4.3.5 Wildlife habitat and species of the Santa Cruz sandhills

Federally endangered animals endemic to the Santa Cruz sandhills, such as found on the District's Olympia watershed property, include the Mt. Hermon June beetle *(Polyphylla barbata)*, the Zayante band-winged grasshopper *(Trimerotropis infantilis),* and the Smith's blue butterfly *(Euphilotes enoptes smithi)*. Other animals that inhabit the sandhills include the rare Western whiptail lizard *(Cnemidophorus tigris)*, and the coast horned lizard *(Phrynosoma croronatum).* The Santa Cruz kangaroo rat *(Dipodomys venustus)* is endemic to the sandhills communities. It was found extensively throughout the Olympia property in 1984 by a student doing her senior thesis (Haynes, 2006), but has not been found since (McGraw, 2004). Plants endemic to the sandhills include the characterizing silver leaf manzanita *(Arctostaphylos silvicola)* and the Ben Lomond wallflower *(Erysimum teretifolium).* Federally protected plants that are restricted to sandhills include Ben Lomond spineflower *(Chorizanthe pungens ssp. hartwegiana)*, and Ben Lomond wallflower *(Erysimum teretifolium)*.

Sand parkland is also home to the sandhills endemic insects: the Mt. Hermon June beetle and Zayante band-winged grasshopper. In addition, sand parkland contains populations of the coast horned lizard and western whiptail lizard, which are far away from the next nearest populations.

Table 4-4 lists special status species of the sandhills community.

Table 4.4 Special status animal species of the Santa Cruz sandhills

Common name	Species name	Status
Western whiptail lizard	*Cnemidophorus tigris*	Locally rare
Coast horned lizard	*Phrynosoma coronatum*	Locally rare
Santa Cruz kangaroo rat	*Dipodomys venustus*	none
Greater roadrunner	*Geococcyx californianus*	extirpated
Mt. Hermon June beetle	*Polyphylla barbata*	Endemic to sandhills; Federally endangered
Zayante band-winged grasshopper	*Trimerotropis infantilis*	Endemic to sandhills; Federally endangered
Smith's blue butterfly	*Euphilotes enoptes smithi*	Federally endangered

Source: McGraw, 2004; Singer, 2008.

Table 4.5 lists special status wildlife species and their predicted occurrence on the City of Santa Cruz watershed lands.

Table 4.5 Special status wildlife species and their predicted occurrence on the City of Santa Cruz watershed lands

Species	Status[1]	Habitat[2]	Occurrence on site
Amphibians			
California red-legged frog *Rana boylii*	FT, CSC	Riparian, marshes, and ponds.	Observed at Mountain Charlie Creek,* Bull Creek,* upper Bean Creek;* possible in Laguna Creeks; occurrence in Newell Creek unknown.
Foothill yellow-legged frog *Rana boylii*	CSC	Creeks, rivers with cobble substrate.	Possible in Laguna, Zayante Creeks. Occurrence in Newell Creek unlikely.
Reptiles			
Southwestern pond turtle *Clemmys marmorata pallida*	FSC, CSC	Creeks and ponds.	Occurs in Loch Lomond Reservoir and Newell Creek.
California horned lizard *Phrynosoma coronatum frontale*	FSC, CSC	Chaparral with loose soils	Possible in Laguna Creek unit adjacent to Bonny Doon preserve.
California whipsnake *Masticophis lateralis*	SFB	Chaparral, valley-foothill riparian, oak, conifer	Possible.
Birds			
Cooper's hawk *Accipiter cooperii*	CSC	Oak woodland, riparian and mixed forests	Potential nesting habitat in mixed evergreen and oak woodlands.
Sharp-shinned hawk *Accipter striatus*	CSC	Nests in coniferous forests	Potential nesting habitat in redwood, Douglas fir forests.
Golden eagle Aquila chrysaetos	CSC	Nests in oak woodland	Possibly may nest in or near the Laguna Creek unit.
Bald Eagle *Haliaeetus leucocephalus*	SE, FT	Forages at Loch Lomond Reservoir	Occasional winter visitor in the Newell Creek unit.
Osprey *Pandion haliaetus*	CSC	Forages at Loch Lomond Reservoir	Regular year-round visitor to the Newell Creek unit.
Merlin *Falco columbarius*	CSC	Winters in the county in a variety of habitats	Likely winters in a variety of habitats.
Long-eared owl *Asio otus*	CSC, SFB	Riparian forests and woodlands adjacent to open foraging areas; requires old nests of other hawks or squirrels	Potential nesting habitat in mixed forests where live oaks are predominant.
Vaux's swift *Chaetura vauxi*	CSC	Nests in hollow of old growth or mature second growth redwood and Douglas fir trees	Potential nesting habitat in mature forests.
Purple martin *Progne subis*	CSC	Nests in cavities of mature trees (e.g., knobcone pines with woodpecker holes, sometimes in chimneys	Potential nesting habitat in knobcone pine forests.
(Continued on next page)			

Table 4.5 Special status wildlife species and their predicted occurrence on the City of Santa Cruz watershed lands (continued)

Species	Status[1]	Habitat[2]	Occurrence on site
Mammals			
Shrew-mole *Neurotrichus gibbsi*	SFB	Redwood forests, other moist forests	Possible
Pallid bat *Antrozous pallidus pacificus*	CSC	Wide variety of habitats; roosts in caves crevices, mines, hollow trees, buildings	Possible
Fringed myotis *Myotis thysanodes*	FSC, SFB	Redwood forests along west coast	Possible
Yuma myotis *Myostis yumanensis*	FSC, CSC	Open forests and woodlands with water nearby; roosts in buildings, caves, crevices	Possible
Townsend's western big-eared bat *Corynorhinus townsendii townsendii*	FSC, CSC	Wide variety of habitats; roosts in caves, tunnels, mines, and buildings	Possible
Santa Cruz kangaroo rat *Dipodomys venustus venustus*	SFB	Maritime chaparral with sandy soils	Possible in Laguna Creek unit adjacent to Bonny Doon preserve.
San Francisco dusky-footed woodrat *Neotoma fuscipes annectens*	FSC, CSC	Riparian and oak woodlands	Observed; likely common inhabitant of woodlands.
Mountain lion *Felis concolor*	*, SFB	Variety of habitats, chaparral may be primary; needs large undeveloped territory	Lion tracks and scat observed on trail in Bonny Doon preserve adjacent to Laguna Creek unit.

Source: City of Santa Cruz, Watershed Resources Management Plan, Existing Conditions Report, 2002.

*California Dept. of Fish and Game, Natural Diversity Database, 2008.

[1] Key to status:
FC = Federal candidate for listing as endangered
FE = Federally listed as endangered species
FT = Federally listed as threatened species
FSC = Federal species of special concern
SE = State endangered
CSC = California species of special concern
SFB = Sensitive fauna in the Santa Cruz Mountains Bioregion.

[2] Type of habitat listed for each species refers only to those habitat types that occur on watershed lands, although elsewhere the species may occur in other habitat types.

4.4 Aquatic habitat and fisheries of the region, the watershed, and District lands

A stream is a complex living system. A healthy stream bed interacts with dissolved nutrients and organic matter in the flowing water to create a dynamic environment, rich with plant and animal life (County of Santa Cruz, 2003). Characteristics of a streambed that influence this dynamic environment include composition, its gradient, and its shape.

4.4.1 Characteristics of a healthy stream

Streams reflect what is happening on the surrounding land. A healthy stream has the following characteristics:

- Cool, clear oxygen-rich water free of pollutants and excess algae.
- Gravel and cobble without too much sand and silt for aquatic insect production and fish spawning.
- Fastwater habitat (riffles and runs) for aquatic insects and foraging fish.
- Frequent pool tail-riffle transitions (glides) for spawning salmonids.
- Deep pool habitat for foraging fish with adequate escape cover for fish to hide from predators and overwintering cover for fish to find shelter behind during high flows.
- A balance of fast water riffles for aquatic insects, fish spawning and feeding, and pool habitats as cover and refuge from high flows.
- Abundant woody material to provide habitat and cover for aquatic and riparian species, and to scour pools.
- Adequate summer streamflow.
- Lush streamside vegetation to stabilize streambanks and provide shade, escape cover for fish and food for wildlife and fish (County of Santa Cruz, 2003; Alley, 2008).

The health of the stream environment depends on several physical factors: water quality; water temperature; the amount of sunlight reaching the stream; the character of the stream bottom (whether bedrock, boulder, gravel, sand, or fine silt); and the volume and timing of water flowing through the stream. Human activities can influence all of these characteristics. Riparian habitats provide food and shelter for a great variety of wildlife. This zone is also critical as a migration corridor for birds and terrestrial mammals, especially where nearby upland development can be a barrier to overland travel.

Coastal streams, such as the San Lorenzo River, are also important for their tidally influenced estuaries during the wet season and freshwater lagoons that develop in summer once sandbars close at their rivermouths. This highly productive fish habitat requires adequate perennial (year-round) streamflow of high water quality and the avoidance of artificial sandbar breaching."

Freshwater lagoons provide valuable steelhead nursery habitat. Freshwater lagoons, which have closed sandbars, are distinct from saline estuaries, which have open sandbars and are tidally influenced. Some would like to breach the summer sandbar at the rivermouth, which would destroy steelhead habitat. Sandbars should be allowed to form in the summer and for lagoons to convert to freshwater with adequate inflow (County of Santa Cruz, 2003; Alley, 2008).

The creeks and tributaries of the San Lorenzo River are home to many aquatic species including invertebrates, fish, reptiles and amphibians, and other aquatic organisms. Many terrestrial mammal and bird species also rely upon aquatic habitats and aquatic prey species.

The San Lorenzo River serves as both a sink and a source of nutrients. It continually receives nutrients primarily from groundwater and eroded soil during storm runoff from adjacent upslope areas, both forested and developed. The river and its tributaries remove inorganic and organic materials from the landscape by water transport. This process contributes to the shape and dimensions of the stream itself. Stream *morphology* is strongly affected by geologic, hydrologic and land-use characteristics and histories, because these factors directly influence the sedimentation rate to the stream and the sediment transport rate by the stream.

4.4.2 The food web in aquatic ecosystems

Riparian vegetation provides much of the organic litter required to support biotic activity within the stream, as well as the large woody debris, which is a key component of aquatic habitat (Spence et al., 1996).

Leaves from the surrounding forest and *riparian zones* provide the energy for the *benthic macroinvertebrate* (BMI) community. In areas of the watershed where sunshine easily reaches the stream bottom, instream photosynthesis begins to play an important role. As deciduous riparian leaves enter streams in the fall, various leaf-mining and leaf-shredding aquatic insects begin to ingest them. As leaves are decomposed by fungi and bacteria, other aquatic insects and macroinvertebrates collect and consume leaf fragments and their microbes often from drifting detritus. Thus, leaves form the energy base for the stream ecosystem.

Adult aquatic insects are vulnerable to predation by other insects, fish, mammals, birds, reptiles and amphibians. In this fashion, streams also provide energy resources to the adjacent terrestrial ecosystems.

Shredder organisms consume leaves, twigs and other large pieces of *detritus*. Biologists have shown that, at least in some instances, these animals may gain as much nutrition from the fungal and bacterial colonies in the detritus as from the wood or leaf itself. Feces and undigested detritus are then in turn food for other organisms, or dissolve into the water. *Collector-gatherer* organisms, such as insects and crustaceans, search benthic areas for the larger material. *Filter-collectors,* such as caddisflies, strain the smaller material from the flowing water of the stream. *Scraper-collectors,* such as snails, are most common in areas of a stream that receive direct sunlight in the summer. They consume the fungi and bacteria that feed on algae, which colonizes every available surface in the stream. *Predators* are at the 'top' of the food chain. These include a few insect larvae which crawl around on the stream bottom and attack smaller insects. Dragonfly larvae may sit and wait near a bank or in shallow, silt-covered areas.

In healthy streams, the relative abundance of these various types of organisms in the benthic macroinvertebrate (BMI) community varies with the size of the stream, which largely determines the abundance of food resources and type of habitat. For example, in small headwater streams, shredder organisms are generally more abundant than scraper organisms. Filter-feeders are generally more prevalent in mid-sized streams. However, the ratio of predators to other organisms remains more stable, no matter what the size of the stream.

The California Stream Bioassessment Procedure (CSBP) is a standardized protocol for assessing biological and physical/habitat conditions of wadeable streams in California. The CSBP is a regional adaptation of the national Rapid Bioassessment Protocols outlined by the U.S. Environmental Protection Agency in "Rapid Bioassessment Protocols for use in Streams and Rivers" (US EPA, 1989). The CSBP utilizes measures of a stream's benthic macroinvertebrate (BMI) community and its physical/habitat characteristics to determine the stream's biological and physical integrity. BMIs can have a diverse community structure with individual species residing within the stream for a period of months to several years. They are also sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution. Biological and physical assessment measures integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality and can provide the public with a familiar expression of ecological health.

Scientists are using CSBP in stream and forest restoration projects, to evaluate biological stream recovery following watershed restoration efforts in Redwood National Park (US Geological Survey, 2007). The study will also model various restoration scenarios to determine the most effective strategy for stream improvement.

4.4.3 Large instream wood as a component of aquatic habitat

Instream wood forms complex habitat for aquatic species, including Federal or State listed threatened or endangered species, such as coho salmon, steelhead and California red-legged frogs.

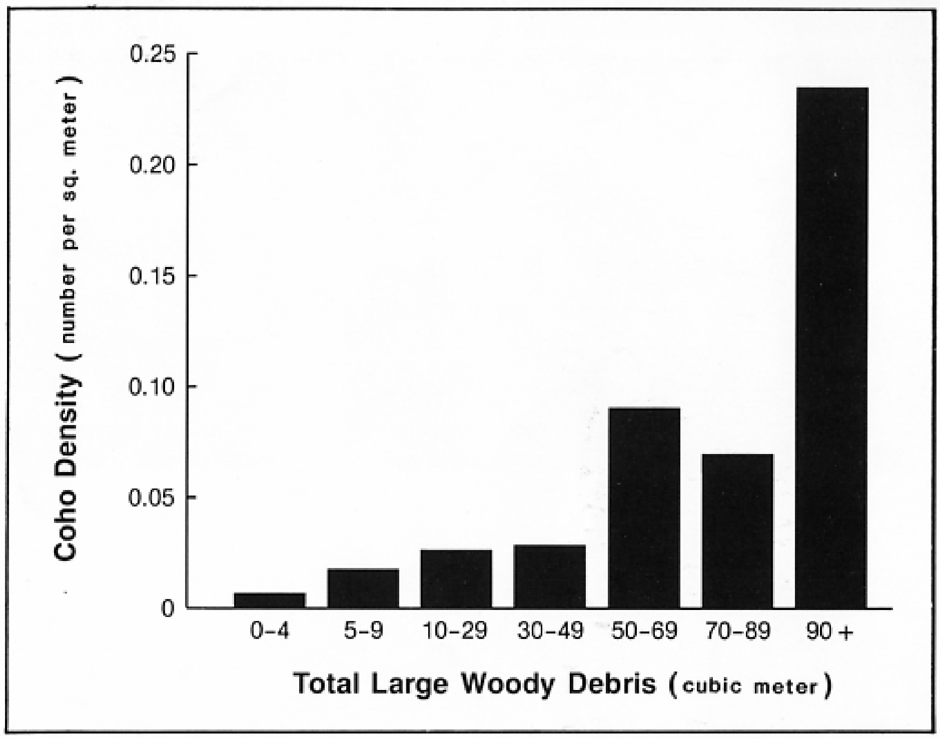
In their research within coastal redwood forests, Keller et al. (1981) found that some instream logs had been in place for over 200 years. Instream wood can provide stable channel and habitat benefits for centuries (Keller et al., 1981; Napolitano, 1998; Benda and Sias, 2002). The wood slowly decays while it remains instream. Organisms ranging from the smallest bacteria, to invertebrates, to larger decomposers are all actively eating the wood. Decomposers, and organisms that feed on decomposers, act as a source of food for aquatic organisms such as salmonids. In this manner, large wood supports an entire local ecosystem. The ability of instream wood to increase productivity and food availability within the stream is valuable to coho salmon and steelhead populations.

Large instream wood is a critical factor in development of pools (Keller et al., 1981). Leicester (2005) found that diameter, length and presence of a rootwad were important in determining if large woody debris (LWD) would scour pools and provide valuable structure to the stream. She found that small diameter wood greater than 20 feet in length, or LWD three feet or greater in diameter, was more likely to be structure-forming, and much of this valuable LWD had the rootwad attached (36-56%). This means that when the County or others cut up an instream tree, only the section with the rootwad attached will likely provide valuable LWD. Pools created by instream wood have several benefits to anadromy, including: a step-wise velocity reduction making upstream migration easier and creating slack waters for adults to rest and avoid predation; habitat and escape cover for juveniles; stabilization of spawning gravels at tails of pools; and increased oxygen concentration and food supply. Pool density per stream length is important to fish density, especially in tributary or headwater streams of the San Lorenzo River watershed.

Stable instream wood aggregations can provide shelter from high winter flows that other forms of cover cannot. During storm events or high winter flows, normal cover objects such as boulders, root masses and small woody debris become turbulent zones where small salmonids may be washed away. During the winter, these objects may become scoured or buried more, reducing their value as cover from streamflow. Large wood accumulations are often large enough to provide still water refuges for small salmonids during high flows. Instream wood may also cause the formation of side channels or backwaters, which can provide refugia against extreme winter streamflows (USDA Forest Service, 2002). These refugia are critical in the survival of juvenile salmonids (especially young coho that hatch earlier in the spring than many young steelhead) and the production of smolt sized fish throughout the watershed. Large instream wood modifies channel morphology and processes, creating dynamic aquatic habitat.

Large wood and wood accumulations create and provide habitat for a wide array of aquatic life including anadromous fish. The amount of instream wood has a direct influence upon the number, size and age distribution of fish populations in streams (USDA Forest Service, 1990). The agency found a direct correlation between the amount of wood in a stream and the number of fish found in the stream, as shown in Figure 4.8.

Figure 4.8 Number of coho salmon found in a stream in relation to amount of instream wood.



Source: USDA Forest Service, 1990.

Large instream wood increases the complexity of stream habitat. Some of the best aquatic habitat in the San Lorenzo River watershed is provided by accumulations of large instream wood or rootwads. Figure 4.9 shows fallen redwood trees forming instream wood in Carbonera Creek. Rootwads provide a substantial cover and habitat within a stream. When such habitats are sampled for fish, they contain high densities of steelhead, larger yearling steelhead, as well as non-salmonid species. Large instream wood can provide still-water refuges for small salmonids during high winter flows. Large instream wood harbors insects that can be a food source for juvenile salmonids. Large instream wood also forms resting cover from predators for adult salmonids during their spawning migrations.

Large instream wood acts as scour objects to create fast waters, form pools, and increase depths of pools, as shown in Figures 4.9 and 4.10. Embedded into a streambank, large wood can both protect the bank from erosion, and create undercut banks that are extremely beneficial to fish. One undercut bank in Waterman Gap was created by a large redwood log embedded into the bank, just upstream of a large boulder with an old growth redwood rootwad holding the boulder in place. The streambank was undercut at least three feet and water depth was 2-3 feet in the pool that it had scoured. This was especially deep for a headwater area. This configuration helped to stabilize the bank and created habitat for smolt-sized, yearling steelhead captured and released at this site during population monitoring (Alley, 2005).

Figure 4.9 Large redwood logs forming instream wood.

Alley 2005

Downstream view of wood that was sieved out of the stream channel by large redwood logs in Carbonera Creek

Figure 4.10 Large instream wood creates habitat favorable to native salmonids

Alley 2004

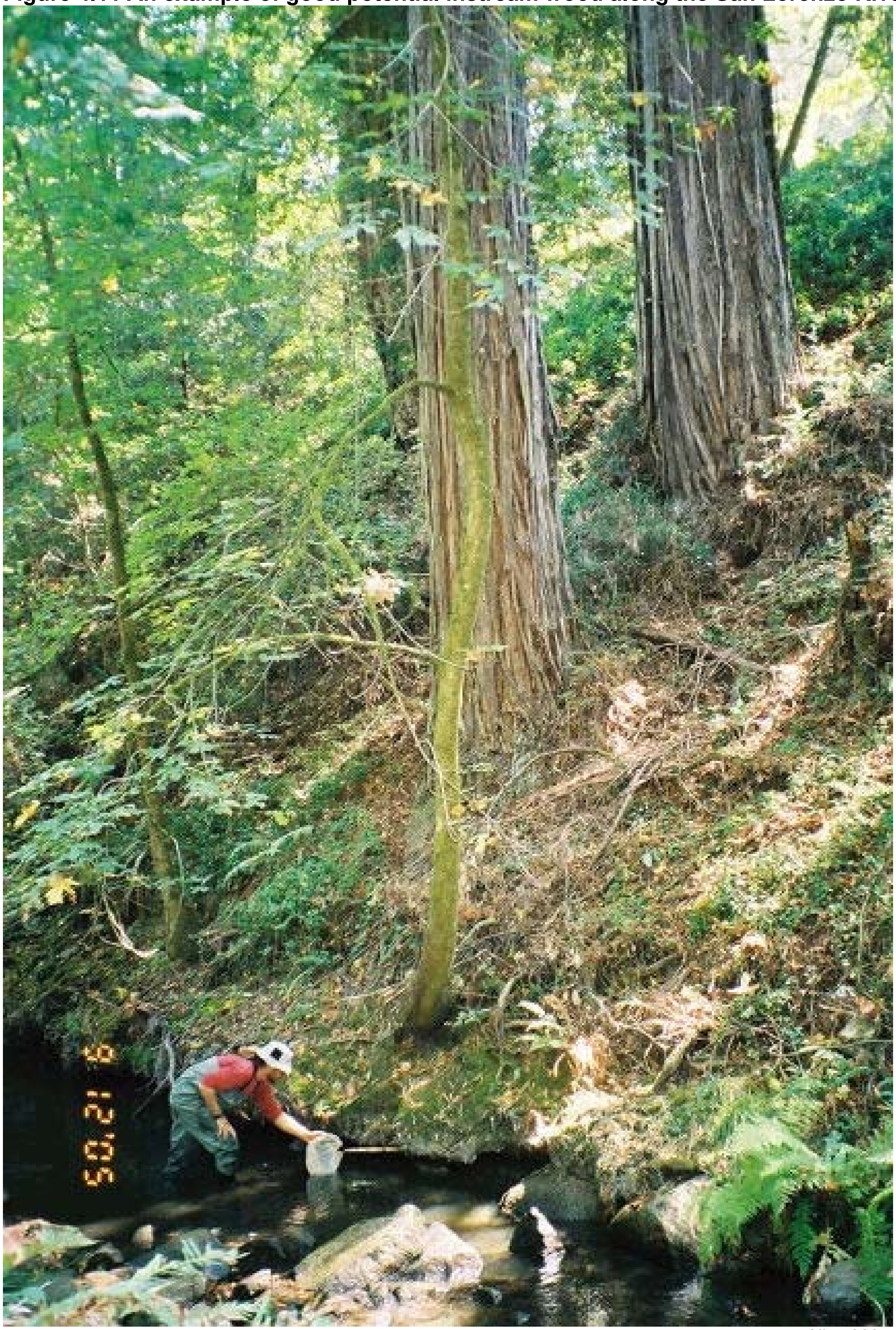
Pool at Waterman Gap, scoured by large, knobby wood embedded in the streambank (right) and large boulder underneath old-growth redwood stump (upper center).

4.4.4 Distribution of large instream wood

Research has shown that many interacting factors influence the distribution, abundance and transport of instream wood throughout a watershed. These factors include climate, slope, geology, forest death, forest growth, bank erosion, mass wasting, stream transport and decay (Keller et al., 1981; Benda and Sias, 2002; Benda et al., 2002). Benda and Sias (2002) identified six processes as key in the abundance and distribution of wood in streams:

- Episodic forest death
- Forest growth
- Chronic mortality
- Bank erosion
- Mass wasting
- Decay
- Stream transport.

Figure 4.11 An example of good potential instream wood along the San Lorenzo River.



Alley 2005

Rare example of old growth redwood still present along the streamside, providing shade, steambank protection, an undercut bank and future large instream wood.

In most of his quantitative studies of instream wood, Benda has found wood storage to be highly variable within streams (Benda et al., 2002). Wood concentrations are highest in small headwater streams and generally decrease downstream (Keller and Swanson, 1979). In old-growth Douglas fir forests in the McKenzie River system of western Oregon, wood concentrations were 48 times higher in a first order tributary than the sixth order mainstem. In the San Lorenzo River watershed, smaller headwater streams are generally steeper and narrower, with a higher potential of input from adjacent slopes, and higher potential for instream wood accumulations. Figure 4.11 shows older redwood trees growing along the San Lorenzo River watershed, providing a potential source of high-quality instream wood.

In small headwater streams, large wood generally remains where it falls, due to lack of sufficient streamflow in tight channels. In mid-sized streams, streamflow can redistribute wood with distinct accumulations that may affect channel form and behavior. In large rivers, wood accumulates around obstructions or in the high water zone on the banks (Keller and Swanson, 1979).

Benda et al. (2002) found diameters of wood to be significantly greater in streams within old-growth forests, compared to streams in second-growth forests. High volumes of stored wood in streams of old-growth forests were primarily due to streamside landsliding (Benda et al., 2002). Another study found recruitment from debris flows to be the single largest source of wood to streams (Benda and Sias, 2002).

Variability of wood distribution and abundance along streams of old-growth redwood forests was related to the frequency of large diameter redwood trees near the channel (Tally, 1980 as cited in Napolitano, 1998). Abundance and distribution of wood within stream networks depend largely upon the mortality rate of the adjacent forest. Chronic mortality, generally higher in second-growth forests than in old-growth forests (Benda and Sias, 2002; Benda et al., 2002), can steadily contribute wood to streams over long periods of time. Stochastic events affecting mortality can cause pulses of wood input to stream systems. Examples of stochastic events are stand-replacing fires, freezes, windstorms, blights, and diseases. Variations in fire frequency affect mortality rates, stand age and age distribution of forests, and thereby the frequency and location of wood input and erosion to streams (Benda et al., 1998).

Bank erosion, generally due to high streamflow storms, causes episodic contributions of instream wood. Rates of erosion depend upon streamflow, location, vegetative density, rainfall intensity, soil type, soil grain size, stability, and reinforcement by roots (Benda and Sias, 2002). Fluvial transport (transport by the stream) depends upon streamflow, channel volume, channel width, slope, obstructions, wood size and wood shape. Pieces that are transported tend to be shorter in length than the channel bankfull width (Benda and Sias, 2002).

The time it takes wood to decay determines the length of time that wood resides within the stream channel. Rates of decay depend upon the species of tree. Instream wood from old-growth redwood logs is very slow to decay, and can remain in the stream for centuries (Keller et al., 1981; Napolitano, 1998; Benda et al., 2002).

Large wood accumulations can span long distances with tightly interlocking pieces of wood, and may persist for decades, until pieces decay or streamflow is high enough to flush the wood downstream (Keller and Swanson, 1979).

4.4.5 Salmonids and other native fishes in the San Lorenzo River watershed

The San Lorenzo River and its estuary are inhabited by at least 25 different species of native fish. These include salmonids and other anadromous fish, which spend part of their lives in the ocean and part in freshwater. The anadromous species of recreational interest are steelhead (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*). These salmonids live as juveniles in freshwater, spend their major growth and adult stages in the ocean, and return to spawn in their natal freshwater streams where they were originally hatched. For more information on the life cycles of coho and steelhead, refer to Appendix A: Fisheries.

Other native fish living upstream of the lagoon/estuary include anadromous Pacific lamprey (*Lampetra tridentata*), threespine stickleback (*Gasterosteus aculeatus*), speckled dace (*Rhinichthys osculus*), coastrange sculpin (*Cottus aleuticus*), prickly sculpin (*Cottus asper*), California roach (*Hesperoleucus symmetricus*), and Sacramento sucker (*Catostomus occidentalis*).

The San Lorenzo River watershed provides over 80 miles of stream habitat for anadromous salmonids (Ricker and Butler, 1979). Coho salmon and steelhead are two species inhabiting the San Lorenzo River watershed upstream of the lagoon that are listed as threatened or endangered under State or Federal law, and are the only species whose populations have been monitored intensively. However, coho salmon rarely reproduce successfully any longer in the watershed. Juvenile coho salmon were detected in 2005 during fall sampling in Bean Creek, indicating successful spawning, 24 years after their last capture during fall sampling. However, a few stray coho adults, presumably from northern drainages, were captured and released at the Felton diversion dam during the winter of 2004 (14 adults), 2005 (16 adults) and 2006 (2 adults) (Alley, 2008).

4.4.6 Life history of native salmonids

Both steelhead and coho salmon are known as "salmonids" and are in the family Salmonidae and salmon genus, *Oncorhynchus*. Technically, steelhead are salmon; not "trout." While the life histories of the two species are similar, they differ in timing of spawning, the ability to spawn multiple times or not, time to maturity, and in certain habitat requirements. For more information about the requirements of native salmonids, refer to Appendix A: Fisheries.

Adult, ocean-dwelling steelhead enter coastal streams and spawn over a longer spawning season than coho salmon, and most migrate and spawn later in the rainy season than coho. Coho spawn mostly from late November through February in this region. Steelhead spawn mostly from January through April, but may spawn as early as November and as late as June.

As soon as streamflows are high enough to breach the sandbar at the river mouth, which forms over the summer, adult steelhead and coho may begin their upstream migration. The sandbar is usually open from late November through June or later, depending upon the winter and spring storm patterns. Both coho and steelhead move upstream to spawn primarily after the peak stream discharge of stormflows.

During low flows between storms, passage impediments may delay upstream migration. These impediments include boulder falls or wide, shallow riffles in the San Lorenzo River gorge, or summer dam abutments further up the mainstem. Adults may wait just below these temporary barriers until sufficient stormflow make them passable. Salmonids may have difficulty locating the fish ladder at the Felton diversion dam during intermediate stormflows.

4.4.7 Monitoring of salmonids in the San Lorenzo River

The District has sponsored annual monitoring of salmonids the San Lorenzo River watershed by certified fisheries biologists since 1993. Figure 4.12 depicts these biologists sampling for juvenile steelhead.

Figure 4.12 Biologists measuring and releasing juvenile steelhead

Collins 2007

Biologists measuring and releasing juvenile steelhead during monitoring in the San Lorenzo River at Henry Cowell Park, a project funded by the District.

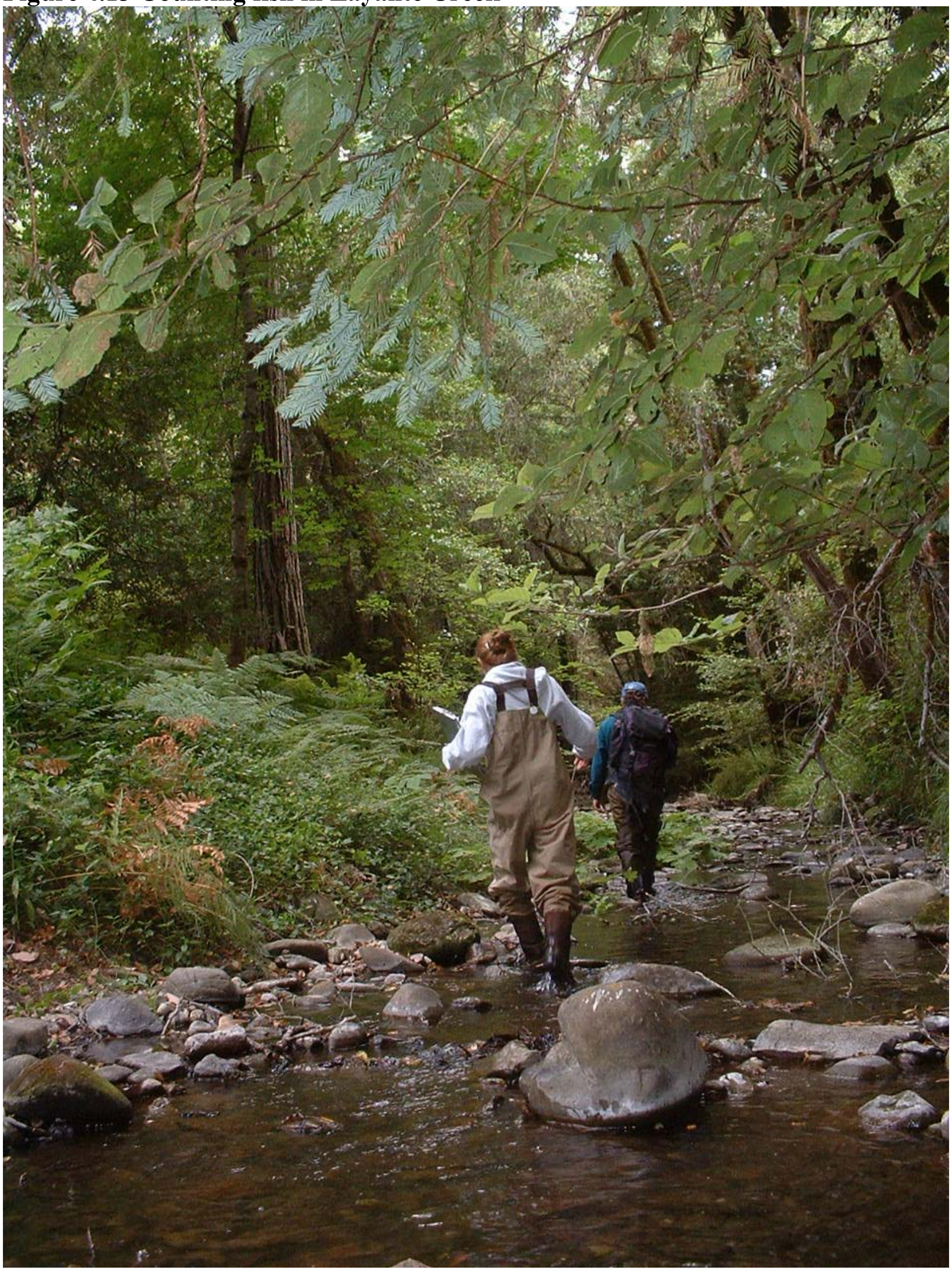
4.4.8 Salmonids on District-owned land

The District's lands and water supply creeks on Ben Lomond Mountain, as depicted in Chapter 1, Figure 1.1, are generally too steep to allow passage of anadromous salmonids, with the exception of Clear Creek. Barriers to fish passage below the District's lands further restrict salmonid access to these areas.

NOAA fisheries biologists surveyed the salmonid populations in the Zayante Creek in the summer 2005 and 2006, after obtaining permission from the District to access portions of the creek that run through District-owned lands. Zayante Creek does not serve as a water source for the District. The survey was part of an ongoing project by NOAA to evaluate the status of salmon and steelhead populations on the Central Coast. The goal of the research project is to provide scientific guidance on how to design and implement a monitoring program in Santa Cruz and Monterey counties, encompassing a systematic, random sampling of streams. Such a monitoring program would enable biologists to evaluate patterns and trends in abundance or distribution over broader geographic areas (i.e., outside of those reaches surveyed) (Spence, 2007). This NOAA monitoring program would supplement other local research and monitoring programs, which are useful in determining trends in abundance or distribution of fish for the specific stream reaches being examined (e.g., Alley, 1993-2007).

Figure 4.13 shows NOAA fisheries biologists documenting fish populations in Zayante Creek on District property.

Figure 4.13 Counting fish in Zayante Creek



Herbert 2007

In summer 2006, NOAA fisheries biologists surveyed 47 randomly selected stream reaches throughout the region, each about 1.0 km in length. The District's Zayante Creek site was one of the reaches sampled. At the District's Zayante Creek site, the biologists visually observed steelhead in most habitats 12 inches deep or greater, as they snorkeled a segment of Zayante Creek upstream of the Mountain Charlie Creek confluence, noting both young-of-the-year and older juveniles. No coho salmon were observed during the survey.

4.4.9 Decline of salmonids on the Central Coast

FishNet 4C is a County-based salmon protection and restoration program that includes the Central California coastal counties of Mendocino, Sonoma, Marin, San Mateo, Santa Cruz and Monterey (Fishery Network of the Central California Coastal Counties, 2007). Following the Endangered Species listings of coho salmon and steelhead trout, County Supervisors from these counties formed FishNet 4C in 1998, to coordinate programs for salmon and fishery restoration.

The focus of the FishNet 4C program is on implementing on-the-ground restoration projects, employing best management practices during maintenance activities, and incorporating aquatic habitat protections into land use regulations and policies.

A UC Berkeley Extension study (Harris and Kocher, 2001) assessed existing county policies and actions throughout the region that may impact salmonid streams. The report identified numerous policy gaps and recommendations for Santa Cruz County, which should be addressed in order to meet FishNet 4C goals.

4.4.10 Decline of salmonids within the San Lorenzo River watershed

Both coho salmon and steelhead were once common and widespread throughout the coastal streams of the Pacific coast. Coho salmon historically occurred in as many as 582 California streams, from the Oregon boarder to their southern limit around the Monterey Bay (Brown et al., 1994). The San Lorenzo River fishery once added significant value both to the county's economy and to the experience of individual anglers. Historically, the two most important anthropogenic impacts on the decline of salmonids in the San Lorenzo River have been identified as sedimentation (i.e., the siltation of rearing pools and spawning beds) and the decrease in summer flows due to pumping and water diversions (County of Santa Cruz, 1979). These and other adverse impacts affecting coho salmon and steelhead in the watershed are discussed further below.

4.4.10.a Decline of coho

The Central California Coast coho salmon forms a separate evolutionarily significant unit (ESU) of the species, extending from Punta Gorda in Northern California to the San Lorenzo River. This means that the San Lorenzo River marks the southern end of the Central California Coast Coho Salmon ESU range. As a result, the challenges this salmon faces are more extreme than those faced by their northern relatives, in terms of elevated stream temperatures and reduced streamflows (NMFS, 2005).

The Central California Coast Coho Salmon ESU was listed under the federal Endangered Species Act as a threatened species in 1996. Accessible reaches of the San Lorenzo River (excluding stream reaches above Newell Creek Dam) were included within the critical habitat designation for the ESU. NMFS (2001) completed a status review of coho populations from the Central California Coast and the California portion of the Southern Oregon/Northern California Coast ESU in response to a petition to protect these populations under the Endangered Species

Act (ESA) (Busby et al., 1996). In 2005, coho were listed as endangered under the federal Endangered Species Act (ESA). Coho salmon south of San Francisco Bay were previously listed as an endangered species by the state of California.

NMFS began the recovery plan for the Central California Coast Coho Salmon ESU in 2005, as required by the federal ESA. Recovery is the process in which listed species and their ecosystems are restored and their future safeguarded to the point that protections under the federal ESA are no longer needed. A variety of actions may be necessary to achieve the goal of recovery, such as the ecological restoration of habitat or implementation of conservation measures with stakeholders (NMFS, 2004).

4.4.10.b Decline of steelhead

NMFS (NOAA Fisheries) adopted a final rule, designating steelhead in the Central California Coast ESU as a federally threatened species, effective October 17, 1997 (NMFS, 1998).

At this time, the designation applies only to naturally spawned populations of anadromous forms of *O. mykiss,* residing below long-term naturally occurring or man-made impassable barriers. The San Lorenzo River is included in critical habitat designated for all accessible reaches, except for stream reaches above Newell Creek Dam. Steelhead south of San Francisco Bay are considered a sensitive species by the state of California.

Loss of steelhead and coho habitat has resulted from dams, water diversions, increased stream water temperatures, stream alterations, sedimentation, excessive scour and other impacts associated with agriculture, logging, mining, urbanization, roads and development. These activities are associated with a dramatic reduction in habitat complexity, including the reduction in large instream wood and an increase in sedimentation (Sanderlock, 1991 as cited in Brown et al., 1994). Napolitano (1998) reports that high quality fish habitat results from complexity and stable conditions.

4.4.10.c Requirements for salmonid rearing habitat

Rearing habitat includes the following characteristics:

- Adequate flows for pool development and to provide fastwater feeding stations for fish
- Escape cover such as undercut banks, rootwads, large instream wood, unembedded cobbles and boulders, surface turbulence, and submerged or overhanging vegetation or debris
- Aquatic and terrestrial insects for food
- Suitable water quality conditions related to water clarity, water temperature, dissolved oxygen concentrations and contaminant levels (Smith, 1982).

Steelhead and coho salmon bury their eggs in gravels. Steelhead larvae live in gravels and cobbles for five to ten weeks from the time the eggs were deposited. The larvae, called alevins, need oxygen rich water flowing through the gravels in order to develop and survive. Alevins also rely on the water flowing through the gravel to remove metabolic wastes. Alevins must swim (emerge) upward through cracks and crevices between gravel particles in the streambed to reach the stream once their egg sacs are absorbed. Gravel clogged with too much fine sediment impedes this effort and increases mortality rate.

Stream dynamics leading to the maintenance of high quality spawning gravel is imperative to population health for steelhead and salmon. Pool depth is also important for all stages of salmonids. Juvenile anadromous fish use spaces under boulders, logs, roots, and undercut banks as escape cover from predation or extreme streamflow. Many other fish species, including the anadromous lamprey, use these same aquatic habitats.

Pools that act as sediment entrapment basins are the first to fill and the last to clear of sediment. Pools are important habitat for anadromous fish, especially in the tributaries and headwater reaches.

Natural processes create aquatic habitats that are critical to salmonids (Spence et al., 1996). Different aquatic habitats are required for different salmonid life stages. For example, graveled-glides are used for adult spawning, fastwater habitat is used for juvenile feeding. Pools provide juvenile cover and feeding areas. Large objects in the channel provide slackwater resting sites for overwintering juveniles and migrating adults.

4.4.10.d Limiting factors for local salmonids

The primary limiting physical factors to fishery productivity in the San Lorenzo River watershed are those that impact spawning access and rearing habitat for juveniles (Ricker and Butler, 1979; Smith, 1982). These limiting factors include:

- Streambed sedimentation with fine sediment
- Reduced stream flow during spawning and rearing
- Shortage of instream wood
- Barriers to adult spawning migration (limits to anadromy)

For a detailed description of limiting factors to salmonids, refer to "Appendix A: Fisheries."

Streambed sedimentation with fine sediment

Background sedimentation is a natural part of the San Lorenzo River. Sedimentation is greatly increased from upland human activities. Sedimentation affects every salmonid life stage within the freshwater environment. Fine sediment reduces water percolation through spawning gravels, impacting survival of salmonid eggs and emerging fry. Fine sediment impacts juvenile rearing habitat by reducing pool depth, and burying boulders and cobbles that juveniles may hide under.

Loss of cracks and crevices between cobbles in riffles decreases aquatic insect habitat and reduces food availability for salmonids. Water turbidity associated with sedimentation also impacts salmonid feeding capability. Salmonids are visual feeders, and need clear water to see their drifting prey. The longer the stream remains turbid after a storm in spring (the most important feeding season for juveniles in small coastal watersheds), the less feeding time available to juvenile salmonids. Thus, turbidity can greatly reduce growth rate.

Aquatic insects inhabit primarily the cracks and crevices between larger cobbles and boulders in fastwater habitat that includes riffles, step-runs and runs. The less fine sediment present in these habitats, the greater the spatial heterogeneity and insect habitat that exists. Thus, if fastwater habitat becomes filled in with fine sediment, burying (embedding) cobbles and boulders, then insect production is reduced, as is food for salmonids.

Sedimentation can affect adult upstream migration by making pools shallower. In order to migrate upstream past instream barriers, salmonids need adequate pool depth below the barrier in order to jump over it. Adult steelhead generally require these approach pools to be at least as deep (some say twice as deep) as the barrier is high, for a successful jump.

Reduced streamflow during spawning and rearing

Winter streamflow, as determined by storm runoff, deepens stream channels making them more easily passable to spawning adult salmonids. Insufficient stormflow may delay or even prevent passage over partial migration barriers, thus limiting access to valuable spawning habitat in tributary streams. Streamflow as a limiting factor is the primary element that defines total available spawning and rearing habitat for salmonids. Streamflow determines drift rate of aquatic insects and, therefore, food supply for salmonids. Less streamflow causes slower water velocities and reduced insect drift rate.

Shortage of instream wood

Benefits of instream wood are discussed at the beginning of this section. The loss of instream wood in the San Lorenzo River watershed is the result of logging, development, and logjam removal policies and practices.

Barriers to adult spawning migration

Barriers to adult spawning migration prevent fish from migrating to and from their natal streams. Barriers range from complete obstructions during all streamflows, to partial impediments, such as riffles that become too shallow to allow fish passage during low streamflow. These barriers may be natural or artificial. Natural passage barriers include waterfalls, bedrock chutes, logjams, large boulder fields, steep riffles, shallow riffles, and bedrock ledges. Natural barriers may be completely removed or altered by storms to allow passage.

Artificial passage barriers include unladdered dams for water storage reservoirs, water diversion dams, summer flashboard dams, weirs, bridge abutments with concrete sills, perched culverts, and instream road crossings.

For a more complete description of limiting factors to salmonids, refer to Appendix A, Fisheries.

4.4.11 Reptiles and amphibians

The following reptiles and amphibians may be found on District owned lands.

The *California red-legged frog*, pictured in Figure 4.14, is a State Species of Special Concern and is federally listed as threatened. It inhabits quiet pools along streams, in marshes, and ponds. Red-legged frogs are closely tied to aquatic environments, adults favoring perennial streams with deeper pools that have considerable escape cover from instream wood or overhanging riparian vegetation in summer. Inhabited pools may vary in depth, with cover being the most important factor (Alley, 2008). Young metamorphs are typically found in shallow, fastwater habitat. Breeding occurs in off-channel ponds and freshwater portions of wetland marshes. The loss of these breeding areas and the introduction of bullfrogs have been key to the disappearance of red-legged frogs in many areas. Recent studies have shown that red-legged frogs are capable of moving distances of up to 2 miles (Bulger, 1999 as cited in Swanson Hydrology & Geomorphology, 2001). The red-legged frog occurs in the Coast Ranges along the entire length of the state.

Within the San Lorenzo River watershed, red-legged frogs have been observed in the lower portion of Laguna Creek from the mouth to Smith Grade and on Mt. Charlie Creek, tributary to Zayante Creek (Berry, as cited in Alley, 2008), and at Fall Creek in Felton (Froke, 2004).

Figure 4.14. The California red-legged frog

Alley 1992

A California red-legged frog in the headwaters of Baldwin Creek, tributary to the San Lorenzo River.

The *foothill yellow-legged frog* is a State species of special concern. It is found in or near rocky streams in a variety of habitats, including mixed conifer, mixed chaparral, and wet meadows (Zeiner et al., 1988). It is rarely found far from perennial or intermittent streams (Stebbins, 1985). Larger adults forage next to deeper pools with abundant escape cover. Small foothill yellow-legged frogs are typically found along sunny, exposed cobble bars near shallow stream habitat that they may quickly retreat into to avoid predators. The young prefer sites with riffles and at least cobble-sized prefer sites with riffles and at least cobblesized substrates (Hayes and Jennings, 1988). A stronghold for foothill yellow-legged frogs is Soquel Creek. They may occur in Laguna or Zayante Creeks (Swanson Hydrology & Geomorphology, 2001).

The *southwestern pond turtle* is a Federal and State Species of Special Concern. This aquatic turtle inhabits ponds, lakes, streams, marshes, and other permanent waters located in woodland, grassland, and open forests below 6,000 ft (Stebbins, 1985). Pond turtles can often be seen basking in the sun on partially submerged logs, rocks, mats of floating vegetation or mud banks. During cold weather, they hibernate upland away from the stream in soft soils where they also may bury their eggs at other times. Nesting activity may occur in flat, sunny upland areas, such as grassy meadows and chaparral as much as 500 meters from water (Rathbun et al. 1993). Pond turtles have been observed at Loch Lomond Reservoir (Swanson Hydrology & Geomorphology, 2001).

California horned lizard is a California Species of Special Concern. This reptile is typically found in riparian habitat (e.g., cobble areas along rivers), chaparral habitat, annual grasslands, and alkali flats. Habitat loss is believed to be the primary cause for decline in this species numbers (Jennings and Hayes, 1994 as cited in Swanson Hydrology & Geomorphology, 2001).

4.5 Ecosystem functions and natural services

This section provides an overview of ecosystem functions and natural services provided by late successional forests, the riparian zone, aquatic habitat, and sandhills communities of the region, in the San Lorenzo River watershed, and on District lands. These ecosystems are most important for the District's water supply.

The District has not identified, mapped, and analyzed species indicating watershed ecosystem health, with surveys, sensitivities to potential management actions and climate change; nor has the District used the California Wildlife Habitat Relationships System to perform a habitat analysis for any wildlife indicator species.

Ecosystem functions include the fundamental natural processes upon which life depends.

To function properly, ecosystems depend on interactions between a number of biogeochemical cycles, including the hydrologic or water cycle, nutrient cycles, the carbon cycle, the flow of energy, ecological community dynamics, and succession. All of these cycles may all be modified by human actions. Refer to Chapter 3, Hydrology, Geomorphology, and Water Quality for additional information on the hydrologic cycle. Refer to Chapter 7, Local Climate Change Assessment for additional information about the carbon cycle.

When ecosystems function properly, they produce natural services that are useful to people. Such natural services include:

- Provision of clean water and air
- Flood control
- Pollination of crops
- Mitigation of environmental hazards
- Pest and disease control
- Carbon sequestration
- Aesthetic, cultural and ethical values associated with biodiversity.

Accounting for these natural services is an increasingly popular area in the field of economics. When natural services are assigned an economic value, protecting ecosystem function tends to make more economic sense. For example, mature forests provide water filtration services that serve to offset water treatment costs. The value of a forest's natural filtration services likely exceeds the potential timber value of the forest. However, unless the forest's water filtration services can be given a monetary value, the forest is likely managed for its timber, which is priced by the board foot.

The District's 1985 watershed protection plan stated the importance of a healthy watershed:

> The attractive natural environment in this area is the major selling point for the watershed's tourist and real estate industries. Vegetation and wildlife are not merely luxuries; they provide a significant contribution to the economy of the area" (San Lorenzo Valley Water District, 1985).

4.5.1 Ecosystem functions of old-growth and late successional forests

As cited by Singer in Swanson Hydrology & Geomorphology (2001), forest ecologist Jerry Franklin (1981) identified four major structural attributes of old-growth forests: live old trees, large snags, large down logs on land, and large down logs in streams. Additional important elements were added by Franklin and Spies (1991A) and included a multi-storied canopy, smaller understory trees, canopy gaps, and a patchy understory.

Forests containing either old-growth or mature second-growth stands are known as late successional forests. Kohm, Franklin et. al., 1997 attribute the following ecosystem functions to late successional forests, which include old-growth and mature second-growth:

- Buffering of microclimate during seasonal climatic extremes
- Producing food for consumer organisms
- Storing carbon which can act as a buffer to large scale climate change
- Retaining high amounts of nutrients and water, including a high capacity for intercepting fog and rain (particularly by the epiphytic lichens and mosses)
- Providing sources of arthropod predators and organisms beneficial to other ecosystems or successional stages
- Maintaining low soil erosion potential

4.5.1.a Ecosystem functions of forest soils

Small streams and headwaters within old growth forests receive most of their nutrients from leaf litter and wood. Forest ecologists have found that nutrient capture and recycling are essential to the long term stability and health of ecosystems. When nutrient inputs no longer balance nutrient loss (such as following disturbance or climate change), nutrients become limited and vegetation changes, initially as increased mortality of the most sensitive species, followed by reduced stature of dominant vegetation (Kohm, Franklin et al., 1997).

Surface soils in old-growth redwood forests typically have a thick litter layer and high organic content, so that rainfall infiltration is high and runoff is low. These qualities reduce erosion and sedimentation (Spence et al., 1996). Old-growth forests store water and release it slowly over time, enhancing stream flow in spring and summer, and reducing surface runoff during winter storms. These filtration and water storage characteristics provide strong rationale for water utilities to manage forested watershed lands toward old-growth conditions.

Because of a thick litter layer and a favorable climate, old-growth redwood forests contain extremely high numbers of the soil invertebrates, fungi, and, to a lesser degree, bacteria. Their role in decomposition of organic litter is a crucial one, since it recycles nutrients needed by the growing trees. Some of the invertebrate species are the centipedes, millipedes, and sowbugs visible to the naked eye, but most are microscopic orbatid mites (Moldenke and Lattin 1990).

The multitude of microscopic soil organisms present in these soils comprise the greatest area of biodiversity in old-growth forests. One square meter of forest soil contains 200,000 orbatid mites within about 75 different species. When other soil invertebrates are included (predatory mites, beetles, springtails, spiders, etc.), that same square meter of soil will have been found to contain 200 – 250 different species of soil invertebrates (Moldenke 1990, Moldenke and Lattin 1990). If one considers the number of microscopic soil invertebrates present, then the Pacific Coastal Temperate Rainforests, including redwood forests, support more biodiversity than tropical rainforests (Moldenke 1990, Moldenke and Lattin 1990).

Fungi also play several important ecological roles in forest soils. Much of the organic material produced in nature is broken down by bacteria, but not so in the forest. Forest debris, twigs, branches, and down logs, is composed of woody tissue containing lignin. Lignin cannot be broken down by bacteria. Only fungi can break down lignin and complete the decay process in woody debris. Consequently forest soils are dominated by fungi, not bacteria. In one gram of healthy forest soil there may be up to 20 miles of thread-like fungal filaments called hyphae (Tugel and Lewandowski 1999)). So unlike other ecosystems where bacteria are the key decomposers, in the forest fungi control the process of decay and decomposition.

But fungi in forest soil don't just associate with dead wood. They are also key players in allowing, supporting, or enhancing the growth of forest trees. A particular type of fungi does this through a symbiotic relationship with the roots of trees. These fungi are called mycorrhizal fungi. They act as an extension of the root system into the soil, providing water and nutrients to the tree in return for sugars (produced by photosynthesis) passed from the tree to the fungi. Mycorrhizal fungi also protect the tree from root pathogens and a number of adverse soil conditions. Studies have shown that mycorrhizal fungi are essential for normal tree growth (Perry 1994).

Threats to beneficial forest soil biota include: (1) the use of pesticides or herbicides, (2) timber harvest activities that incorporate soil disturbance or compaction, (3) catastrophic wildfire (i.e., a fire that is unusually hot or of long duration), and (4) soil erosion (U.S. NRCS 2004).

In redwood forests, vascular plant epiphtyes grow in great abundance only on old-growth redwood trees located within 10 kilometers of the ocean (Sillett and Bailey, 2003). Locally, the greatest epiphyte growth occurs on Douglas-fir trees, rather than redwood (Singer, 2008). The most abundant vascular plant epiphyte on redwood is the leather fern (*Polypodium scouleri*) (Sillett and Bailey, 2003). It is found in large aggregations (mats) on branches and trunks high in the redwood canopy. Of 27 redwoods sampled along the coast of Del Norte and Humboldt counties, 13 had fern mats of leather fern. Other ferns that grow as epiphytes on redwoods include the licorice fern (*Polypodium glycyrrhiza*), sword fern (*Polystichum munitum*) and lady fern (*Athyrium filix-femina*) (Sillett and Van Pelt, 2000; Sillett and Bailey, 2003).

Other epiphytes found in old-growth canopies, and typically found in greater abundance in the Santa Cruz Mountains, are mosses and lichens. Mosses and lichens provide habitat for invertebrates, retain nutrients and moisture for forest trees, and organic material for soil. Nitrogen-fixing canopy lichens, like the Lungwort (*Lobaria pumonaria*), fall or are blown off of trees and provide an important nitrogen source for forest soils. During the winter fragments of this large cabbage leaf-like lichen are an important browse for deer in old-growth stands. They are generally associated with late successional forest ecosystems (100+ years).

4.5.1.b Ecosystem functions of snags

An old-growth forest contains many snags and large downed logs in various stages of decay, which are found both on the forest floor and in streams. Both snags and downed logs play an important role in the forest ecosystem.

A snag is a dead or partly dead tree at least four inches in diameter at breast height (dbh) and at least six feet tall (San Lorenzo Valley Water District, 1985). Large-diameter snags provide the greatest variety of nesting habitat and stand longer than smaller snags (Bull et al., 1997). Large dead snags in an old-growth forest can stand for over 200 years. In the redwood forests of the Santa Cruz Mountains, almost all snags are provided by Douglas-fir, an important associate of redwood in redwood forests. Redwoods are so long-lived that they may never die from old-age, whereas Douglas-firs in the Santa Cruz Mountains seldom, if ever, live beyond 400 years. Douglas-firs are also susceptible to death from fire, and redwood generally is not. So the recruitment of large snags and large down logs in a redwood stand is largely dependent on a component of Douglas-fir trees in the stand (Singer, 2008)..

The role of snag-dependent species has been recognized in the regulation of insect populations (San Lorenzo Valley Water District, 1985). Most birds and many mammals that depend on snags are insectivorous, and represent a major portion of the insectivorous animals of a forest. In combination with other disturbances, forest insect outbreaks can pose a serious threat to forest health. In many instances, birds have reduced outbreaks of forest insects (San Lorenzo Valley Water District, 1985). Intact populations of all trophic levels help to minimize outbreaks of "pest" species. Bats, birds, and other insectivorous animals depend upon snags for both food sources and locations for roosting or nesting to support their populations. Leaving snags intact can minimize the impacts of pest species.

The role of snags within a forest is often overlooked. Snags are commonly removed during timber operations, for public safety, to reduce fire hazard, or to lessen the risk of instream log jams. To provide a continuous supply of snag habitat, a certain number of green trees, generally Douglas-firs, should be designated to eventually become snags. Snags can also be created artificially, by girdling or other means, in managed forests (Bull et al., 1997). However, managed forests may never produce the large snags that are essential for pileated woodpeckers. Pileated woodpeckers are a keystone species in that only they can create the large cavities needed for roosting, denning, or nesting by many other forest birds and mammals (Bull and Jackson 1995). Information relating to snags can be input into models to determine the number of green trees necessary to provide ample snag habitat in a managed forest (Bull et al., 1997). Information would include fall rate of standing snags, snag density, live stem density and mortality rate.

4.5.1.c Ecosystem functions of downed logs

A log is defined as a tree, branch or top with large end diameter of at least 6 inches and/or a length of eight or more feet (Bull et al., 1997). Downed logs play a critical ecological role in forests. Logs on the forest floor, especially large logs, serve as reservoirs for water and nutrients. They are sites for bacterial nitrogen fixation, fungal and other decomposers, refuge for invertebrates, small vertebrates, mycorrhizal fungi, and other organisms during fire. They also serve as seed banks and wildlife habitat. Downed logs act to stabilize slopes and prevent erosion.

Decaying logs store large volumes of water, which can be used by other organisms throughout the year. They absorb significant quantities of water early in the decomposition process (Maser et al., 1979). Holding water throughout the year benefits other plants and animals and maintains a higher moisture level than otherwise available within the forest ecosystem. Combined increases in moisture and nutrients in downed logs make them an excellent site for plant propagation. Many animals store seeds in logs, which become seed banks for forest regeneration. Seeds germinate and grow rapidly, due to increased availability of water and nutrients, and shelter provided by the structure of the log.

Logs are classified by their level of decay. Table 4.6 describes the characteristics of five decay classes, with Class 1 logs showing the lowest level of decay. Each class provides different habitat qualities to wildlife. Rates of decay depend upon the species of tree, surrounding habitat, external forces (such as by windthrow, other trees falling or damage by bears), climate, slope, moisture, and number of decomposers in the log.

Class 3 and class 4 logs are important in the colonization of mycorrhizal fungi, which are essential for the healthy growth of live trees. A symbiotic relationship is formed between roots of the fungi and the roots of vascular plants (Maser et al., 1979). Mycorrhizal translates literally as *fungus-root* and defines the common association between specialized soil fungi and the fine roots of nearly all forest plants. Mycorrhizal associations represent one of the more widespread forms of natural symbioses in terrestrial ecosystems. These symbiotic relationships have evolved over the millennia such that each partner depends on the other for survival (Kohm, Franklin et al. 1997). Mycorrhizal associations are necessary for the survival of many trees including pines and Douglas fir (Maser et al., 1979).

Downed logs help to regenerate forests, and the presence of large old snags and downed logs are key characteristics of old growth forests. It is important for land managers to conserve and enhance log recruitment.

Table 4.6 Guide to determining decay class of downed logs in a forest.

Decay Class	Structural Integrity	Texture of Rotten Portions	Color of Wood	Invading Roots	Branches and Twigs
1	Sound, freshly fallen, intact logs	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark
2	Sound	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs are gone and remaining fine twigs have peeling bark
3	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish-brown or original color	Sapwood only	Branch stubs will not pull out
4	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Through-out	Branch stubs pull out
5	None, piece no longer maintains its shape, it spreads out on ground	Soft; powdery when dry	Red-brown to dark brown	Through-out	Branch stubs and pitch pockets have usually rotted down

Source: Gibbons et al., 2004.

4.5.2 Ecosystem functions of the riparian zone

The *riparian zone* is the area that serves as the interface between the stream or lake and the surrounding upland plant communities. Because of the presence of water, nutrient-rich sediments and organic matter, riparian zones are often characterized by high plant species diversity. Riparian zones also serve as movement corridors for wildlife.

The term *riparian zone* is defined generally in different ways and from different perspectives in scientific literature (Alley et al. 2004). This document uses the definition after Gregory et al. (1991), who defined a riparian zone functionally as a "three-dimensional zone of interaction between terrestrial and aquatic ecosystems." These scientists proposed a conceptual model of riparian zones that integrated research findings from different fields to include geomorphic processes, plant succession, and attributes of stream ecosystems (Herbert, 2004). Ehlers and de Guzman (2002) expanded on Gregory's functional definition by emphasizing gradients within riparian areas:

> Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines.

4.5.2.a Nutrient distribution and flooding

According to Gregory (1988), "If management agencies adopt perspectives of riparian zones that do not address critical ecosystem processes, the integrity of riparian resources cannot be insured."

Disturbance in the form of flooding is important in transporting particulate and dissolved organic matter, and nutrients. Flooding is also serves to export organic material from forests to adjoining ecosystems and their inhabitants. When streams overflow, a large surface area of litter and detritus is exposed to the water, often for a long time. During this time, significant leaching and fragmentation occur, and both dissolved and particulate organic materials are removed from the floodplain (Taylor et al., 1990).

Large floods move great quantities of wood downstream and onto the flood plain. Low frequency, high magnitude floods add much material to streams. Physical abrasion is the most powerful mechanism for removing stable pieces of wood from streams and rivers. Sand and gravel carried at flood velocities abrade large pieces of wood. Abrasion is greater in high gradient or sediment-rich streams than in gentle, spring-fed or low-gradient streams and rivers (Sedell, et al., 1998).

Spence et al. (1996) describe the functions and benefits of riparian corridors:

> Riparian and floodplain areas are the critical interface between terrestrial and aquatic ecosystems, serving to filter, retain, and process materials in transit from uplands to streams. Riparian vegetation plays a major role in providing shade to streams and overhanging cover used by salmonids. Streamside vegetation stabilizes stream banks by providing root mass to maintain bank integrity, by producing hydraulic roughness to slow water velocities, and by promoting bank building through retention of sediments. Riparian vegetation also provides much of the organic litter required to support biotic activity within the stream as well as the large woody debris needed to create physical structure, develop pool-riffle characteristics, retain gravels and organic litter, provide substrate for aquatic invertebrates, moderate flood disturbances, and provide refugia for organisms during floods. Large woody debris performs important functions in streams, increasing channel complexity, creating hydraulic heterogeneity, and providing cover for fish. Large wood also provides critical habitat heterogeneity and cover in lakes, estuaries, and the ocean. In addition to the aquatic functions that riparian areas perform, they typically provide habitat and create unique microclimates important to a majority of the wildlife occupying the watershed.

NOAA Fisheries (2000) recognized that human activities may impact properly functioning conditions for federally protected species, such as steelhead. According to NOAA Fisheries (2000):

> The existence of native vegetation along stream corridors is a condition that can support essential habitat processes such as temperature control, bank stability, stream complexity over time, the filtering of pollutants, or contributions of large logs and other woody debris to a stream.

4.5.2.b Hydrologic function

Riparian zones buffer against increases in sediment input, and regulate sediment transport. The riparian zone buffers and modulates extreme flood streamflows.

Healthy riparian zones protect streambanks from being damaged by objects transported during extreme flood events. Root systems of the riparian corridor armor stream banks against erosion, even when roots are completely exposed. Stems, branches and exposed roots moderate current velocity by increasing hydraulic roughness (Spence et al., 1996). Streambanks with a five-centimeter thick root mat were observed to retard erosion up to 20,000 times more effectively than streambanks lacking vegetation (Smith, 1976 as cited in Keller and Swanson, 1979). Keller and Swanson (1979) found that root systems of riparian trees protect a length of stream bank approximately five times the diameter of the tree. Streambanks protected by root networks of riparian trees often create undercut banks, another habitat highly desirable for anadromous fish. Undercut trees may eventually fall into the stream, supplying large instream wood.

Average channel width and slope are affected by riparian vegetation density (Keller and Swanson, 1979). Tree-lined channels tend to be narrower and steeper than alluvial channels with fewer trees, even though they transport the same amount of water and sediment (Maddock, 1972 as cited in Keller and Swanson, 1979). The steeper narrower channels are able to move more sediment along, compared to wider, flatter, channels that aggrade and fill with sediment. Therefore, healthy riparian corridors can help to reduce sedimentation of channels. The increased input of large instream wood from healthy riparian zones also increases potential scour objects and sediment regulation functions. In larger channels, the riparian corridor buffers flood events and settles out sediments, which fertilize the alluvial riparian zone.

4.5.2.c Water quality enhancement

Healthy riparian ecosystems improve water quality by reducing nitrates and bacterial concentrations. Riparian vegetation regulates heat gained and lost from the sun and air or wind. Temperatures in the riparian zone tend to be cooler during the day and warmer during the night than exposed areas (Spence et al., 1996). Greater convective exchange occurs when temperatures across the air / water gradient are the most extreme (Spence et al., 1996). Riparian vegetation creates a shaded microclimate of relatively high humidity, moderate temperatures, and low wind speed. These conditions tend to reduce both convective and evaporative energy exchange between the air and the water, by minimizing temperature and vapor-pressure gradients (Spence et al., 1996). In this way, riparian corridors moderate both extreme air and water temperature changes. The removal of riparian vegetation increases maximum water temperatures and increase daily temperature fluctuations in smaller streams of the Pacific Northwest (Spence et al., 1996).

4.5.2.d The riparian zone in the San Lorenzo River watershed

Protected areas such as Henry Cowell State Park provide insight into the condition of pre-settlement riparian areas. The riparian zone was much wider historically, and there were large numbers of old growth redwood trees near stream banks.

At Henry Cowell State Park, frequent flooding inundates the entire flat area from the railroad tracks to Highway 9. As a result of this flooding, the soil is rich, fine and deep. Riparian vegetation has adapted to conditions such as these. Riparian woodland plant communities in the San Lorenzo River watershed provide shade, contribute nutrients to the waterway from leaves, contribute large wood, encourage percolation of rain, and resist sediment flow and overland runoff to the waterway on steep terrain. Riparian zones of the San Lorenzo River watershed have the highest breeding bird density of all habitat types in the area (Camp, Dresser & McKee, 1996).

Locally, the Santa Cruz County Environmental Planning Department defines the riparian corridor from a functional perspective:

> The riparian corridor is the area adjacent to the stream that supports a plant and animal community adapted to flooding or wet conditions. Willows, alders, and cottonwoods are common riparian tree species. Redwood and Douglas fir often inhabit the riparian corridor, particularly in the upper reaches of the watersheds. All of these tree species contribute to bank stability, shade, undercut banks, and woody material within the stream.

However, the county uses prescribed distances from waterbodies to delineate the size of riparian corridors:

- Lands extending 50 feet (measured horizontally) out from each side of a perennial stream. Distance is measured from the mean rainy season (bankfull) flowline.
- Lands extending 30 feet (measured horizontally) out from each side of an intermittent stream. Distance is measured from the mean rainy season (bankfull) flowline.
- Lands extending 100 feet (measured horizontally) out from each side of a lake, wetland, estuary, lagoon or natural body of standing water.
- Lands within an arroyo located within the Urban Services Line or Rural Services Line.
- Lands containing riparian woodland (cottonwood, sycamore, alder, box elder, etc.).

(County of Santa Cruz, 2003).

While set distances provide uniformity and predictability from a regulatory standpoint, these prescriptions are not based on biological or ecological relationships at any one location, so the extent of riparian vegetation will vary, depending on local conditions.

(Alley et al., 2004b) describes the variation in size and locations of riparian zones:

> Depending on the configuration of the valley where the riparian corridor occurs, riparian corridor width can range from a narrow strip along the bottom of a canyon (10s of feet wide), to wide swaths of dense vegetation where the canyon opens up into a wide valley floor (100s of feet wide). The function of riparian corridors also differs by location. In the case of a narrow canyon, the roots of riparian vegetation stabilize stream banks, provide scour objects that improve fish habitat, reduce direct sunlight

> and keep water temperatures cool, and provide wood to the channel that act as grade control and escape cover elements. In addition to stabilizing stream banks and providing for improved habitat conditions, riparian corridors on wide valley floors reduce water velocities during flooding events and filter out fine sediment, resulting in improved water quality.

Healthy riparian zones increase native fish populations, to improve sport and commercial fisheries. Benefits of an intact riparian corridor were explained in the Santa Cruz County General Plan (County of Santa Cruz, 1984):

> The riparian corridors adjoining watercourses protect fisheries resources by maintaining low water temperature through shading, providing cover and nutrients, and by trapping sediment before it can reach the watercourse. The roots of this vegetation provide soil strength and prevent or reduce streambank erosion, thereby protecting fisheries resources as well as bridges, roads, and structures which would otherwise be endangered by high stream flows.

The Soquel Creek Storm Damage Recovery Plan, prepared by the Soil Conservation Service after the flood event of 1982, identified an additional important benefit provided by riparian vegetation. It reported that during high stream flows, riparian woodlands filter many logs and other woody debris out of the stream. Contrary to a commonly held belief, the report stated that riparian woodlands trap more woody debris during high flows than they contribute, and reduce the potential for damaging log jams downstream (as cited in San Lorenzo Valley Water District, 1985).

4.6 Human impacts to biotic resources

This section discusses the general problem of human disturbance to native plant communities, wildlife and fisheries habitats, and ecosystem function. It then discusses specific impacts within the San Lorenzo River watershed, and how they impact local biotic resources.

Disturbance may disrupt ecosystem functions in ways that impair the natural services provided by healthy ecosystems, such as provision of clean water. Watershed disturbance may be human induced, or from natural causes. Watershed disturbances may be chronic or acute and may lead to chronic or acute biological responses. Impacts may combine and increase over time, creating cumulative watershed impacts.

Unlike natural disturbances, human induced disturbances are not patchy. Human induced disturbances fragment habitat and ecological communities at a scale in size or time that overwhelms their resiliency. Habitat fragmentation is a serious threat to diversity and species persistence. Landscape scale alteration permanently alters the landscape and degrades ecosystem functions. Potential biodiversity and abundance is reduced due to the reduction in diverse habitats and niches. Habitat loss through conversion to other land uses is the major cause of species endangerment (Jones & Stokes, 1987).

Since the 1800s, the San Lorenzo River watershed has been altered by human land use practices, water diversions, and water use. This section describes these practices and their impacts to plant communities, and wildlife habitats.

4.6.1 Development

Development, which includes housing, roads, and landscaping, has reduced and degraded plant communities and wildlife habitat. While much of the San Lorenzo River watershed remains in open space, development has severely fragmented the landscape. Roads have created miles of linear swaths through viable habitat. Some wildlife species, including the mountain lion, bobcat, and golden eagle, are very sensitive to human disturbance. Some species require large areas, 100 acres or more, of undisturbed habitat (San Lorenzo Valley Water District, 1985).

Development of sandhills habitat increases the area of impermeable surfaces (e.g., roofs, roads), results in increased run off directly to streams, and thus, reduced percolation into the aquifer. Though the District owns a large tract of sandhills habitat, which it manages for its value to the aquifer, land use on private property containing sandhills habitat has the ability to significantly impact the aquifer as well.

Many riparian corridors are now developed with houses and roads. Riparian ecosystems have been removed, altered or destroyed at an alarming rate throughout the state (Jones and Stokes, 1987; California Riparian Habitat Conservation Program, 2003). In the past 150 years, the state of California has lost over 89% of riparian ecosystems (Jones and Stokes, 1987; Birdlife International, 2003). Losses of riparian ecosystems have been primarily due to agriculture, logging and development. Within the San Lorenzo River watershed, the primary causes of riparian habitat loss have been logging, development, roads, and invasive exotic species.

According to the San Lorenzo River Watershed Management Plan (County of Santa Cruz, 1979) a typical private property of the San Lorenzo River watershed, including structure, yard and driveway, creates about one half acre of disturbed area. Light pollution, noise pollution, and impacts from pets may expand this area of disturbance. While the rights of property ownership are of great political importance from the local to national scale, these rights must be balanced with responsibilities, to ensure that individual activities do not adversely affect resources that belong to all citizens (Spence et al., 1996).

4.6.2 Roads

Roads impair hydrologic function, fragment habitats, and are sources of pollution. Trombulak and Frissell (2000; cited by Herbert, 2004) summarized the ecological effects of roads of all types on terrestrial and aquatic communities, finding:

> Not all species and ecosystems are equally affected by roads, but overall the presence of roads is highly correlated with changes in species composition, population sizes, and hydrologic and geomorphic processes that shape aquatic and riparian systems.

These studies used roads as “the best available general proxy of cumulative effects associated with land use and human access” (Trombulak and Frissell, 2000 as cited by Herbert, 2004).

The National Marine Fisheries Service (NMFS, 1996 as cited by Herbert, 2004) used road density as an indicator of watershed condition in formulating guidelines for salmon restoration on the Pacific coast. NMFS designated road densities greater than 3 miles per square mile of watershed, as an indication that the watershed is “not properly functioning.” Road densities have been found to be negatively correlated with fish stocks (Lee et al. 1997, as cited by Herbert, 2004).

Cars pollute the air and leave petrochemical residues on the road surface, which washed into streams as urban runoff. Cars create light and sound pollution. Litter thrown from cars increases trash and can attract animals, increasing the risk of road kill. Remote rural roads facilitate illegal dumping of trash and household appliances. Trash dumped down steep ravines from remote roads often finds its way into streams. Fires can be started in remote areas by people carelessly tossing cigarettes or matches out car windows.

Roads are vectors of distribution for exotic plant species. Road corridors are often lined with non-native plants, which then proliferate throughout the watershed.

Most of the main roads in the San Lorenzo River watershed follow the stream channel, altering both physical and biological characteristics of riparian habitat. Streams have been straightened in some areas to accommodate the roadbed.

4.6.3 Logging

Landscape-scale logging in the San Lorenzo River watershed, around the turn of the previous century, imposed large-scale destruction of the old-growth forest ecosystem, and altered community structure and species interactions. By drastically altering local stream ecology, logging heavily impacted local salmonid populations (Spence et al., 1996). After clear-cutting, the forest grew back densely with trees of similar age and size. The resulting, more even-aged forest, is more susceptible to catastrophic fire. It also supports lower biodiversity, lacking the diversity of structural features associated with old-growth forests.

4.6.3.a Habitat degradation from logging

Little was recorded of the ecology and species prior to the clear-cutting in this area. Some species, still living in the region, such as the marbled murrelet (*Brachyramphus marmoratus*), undoubtedly had a much greater area of suitable breeding habitat prior to the almost complete removal of their primary habitat, old-growth forest.

Timbering has degraded riparian corridors throughout the watershed. Hardwoods have replaced conifers in many riparian areas. Downed wood from hardwoods tends to be smaller, more mobile, and shorter-lived than that derived from conifers and does not function as well in retaining sediment (Spence et al., 1996).

Table 4-7 summarizes the impacts of forestry operations on coastal streams, within the fog belt. (For more information about impacts outside the fog belt, refer to Table A-1).

Table 4-7. Coastal forest practices in the fog belt and their potential impacts to local coastal stream environments, habitat quality, and salmonid growth and survival

Forest practice	Types of potential impacts:		Potential consequences for salmonid growth and survival
	to physical stream environment	to quality of salmonid habitat	
Timber harvest in coastal riparian areas	Increased incident solar radiation	Increased stream temperature; higher light levels; increased autotrophic production; more food available	Reduced growth efficiency; increased susceptibility to disease; changes in growth rate and age at smolting- faster growth rate only if food supply overshadows metabolic costs of higher water temperature
	Decreased supply of large wood to the stream	Reduced cover; loss of pool habitat; reduced overwintering shelter from stormflows; reduced storage of gravel and organic matter; loss of hydraulic complexity	Increased vulnerability to predation; lower winter survival; reduced carrying capacity for juveniles; less spawning gravel; reduced food production; loss of species diversity
	Addition of logging slash (needles, bark, branches)	Short-term increase in dissolved oxygen demand; increased amount of fine particulate organic matter; increased cover	Reduced spawning success; short-term increase in food production; increased survival of juveniles
	Erosion of streambanks	Loss of cover along edge of channel; increased stream width; reduced depth	Increased vulnerability to predation; reduced carrying capacity and survival for juveniles
		Increased fine sediment in spawning gravels and food production areas; loss of cover from embeddedness of boulders; loss of cover from loss of deep water	Reduced spawning success; reduced food supply, reduced juvenile survival and carrying capacity
Timber harvest on coastal hill slopes; forest roads	Altered streamflow regime	Reduced summer baseflow due to lost fog drip; reduced retention of groundwater, aggradation of the streambed and faster transpiration rate of the younger forest after harvest	Decreased survival and reduced carrying capacity for juveniles
		Increased surface runoff during winter storms; increased peak stormflow events	Embryo and sac fry mortality caused by increased bed-load scour and movement
	Accelerated surface erosion and mass wasting	Increased fine sediment in stream gravels; streambed aggradation; increased turbidity from suspended sediment during important spring feeding period	Reduced spawning success; reduced food abundance; loss of rearing habitat and overwintering refuge, reduced feeding efficiency, slower growth, decreased survival and reduced carrying capacity for juveniles
		Increased supply of coarse sediment	Potentially increased spawning success and increased rearing capacity where large wood is present to segregate gravels and cobbles from fines
		Increased frequency of debris torrents; loss of instream cover in the torrent track; improved cover in some debris jams	Blockage to migrations; reduced survival in the torrent track; improved overwintering habitat in some torrent deposits
	Increased nutrient runoff	Elevated nutrient levels in streams	Increased food production
	Increased number of roads and crossings	Physical obstructions in stream channel; increased input of fine sediment from road surfaces and erosion from gully formation beside roads and landslides initiated by road failures	Restriction of upstream movement; reduced feeding efficiency, reduced rearing habitat, decreased survival and reduced carrying capacity for juveniles
Scarification & slash burning (preparation of soil for reforestation)	Increased nutrient runoff; Inputs of fine inorganic and organic matter	Short-term elevation of nutrient levels in streams. Increased fine sediment in spawning gravels and food production areas; short-term increase in dissolved oxygen demand	Temporary increase in food production. Reduced spawning success

Source: (Alley, 2008; Noss, ed., 2001).

In addition to problems noted in "Chapter 3: Hydrology, geomorphology & water quality," mass soil movement in forested watersheds is often triggered by road construction (Brown, 1991). The network of unpaved logging roads and skid trails in Santa Cruz County is an acknowledged problem (Santa Cruz County Planning Department, 1998). Roads built on slopes exceeding 50% often result in debris flows (Santa Cruz County Planning Department, 1998). Figure 4-15 shows a failed logging road in the Fritch Creek area of Boulder Creek. Fredriksen (1965, 1970) noted that landslides from mid-slope roads constructed across a patch-cut watershed produced sediment concentrations 34 times greater than expected from observations made during the pre-treatment period. Herbert (2004) cited the work of Trombulak and Frissell (2000), which summarized the ecological effects of roads of all types on terrestrial and aquatic communities, finding that:

> Not all species and ecosystems are equally affected by roads, but overall the presence of roads is highly correlated with changes in species composition, population sizes, and hydrologic and geomorphic processes that shape aquatic and riparian systems.

Figure 4-15. Logging road-cut failure on Fritch Creek

Collins, ca. 1998

Aftermath of logging on Fritch Creek, tributary to Boulder Creek, with evidence of road cut failure and bare, eroding slopes contributing sediment to ephemeral tributary.

Logging with heavy equipment and log skidding degrades the forest floor's moist duff layer, with its multitude of microbes, fungi and root systems that decompose and recycle nutrients in the leaf litter. Soil may become compacted, with overland water runoff increasing during storms.

Eroding soil from forests that are logged using selection cutting may enter stream channels and degrade both spawning and rearing fishery habitat, as illustrated in Figure 4-16 (Alley, 2008).

Following such practices, turbid conditions may last longer after storms, thus preventing visual drift feeding by salmonids. Removal of conifers in riparian corridors may reduce stream shading, and weaken streambank integrity provided by tree root systems. Logging along streams removes the source of large, durable instream wood that is critical for high-quality fishery habitat.

Figure 4-16. Selective cutting of conifers on steep slopes above a steelhead stream

Alley 1998

Disturbed slope, sun-exposed after selective logging of hillslope down to edge of headwater steelhead stream, Santa Cruz County.

4.6.3.b Loss of large instream wood after logging

As discussed in Section 4.4, large woody material is an essential part of a healthy aquatic habitat. Past clearcutting of old-growth redwoods resulted in a diminished recruitment of large woody material to streams, and current state logging regulations allow cutting and removal of existing redwoods every ten to twelve years.

According to the San Lorenzo River Salmonid Enhancement Plan (Alley et al., 2004a) the San Lorenzo River system has much less instream wood than other local steelhead and coho streams, including Gazos, Scott and Waddell Creeks:

> For example, Leicester (2005) found reach densities of large woody material (at least 1 foot in diameter) ranging between 18 and 65 pieces per thousand feet in the active (bankfull) channel of relatively small Gazos Creek. In surveyed reaches of the San Lorenzo and tributaries, the density range was only 2-32 pieces per 1000 feet (Alley et al., 2004a). One site, in Henry Cowell Park, had 65 pieces per 1000 feet.

4.6.4 Water diversions and pumping

In a climate where rain is seasonal, human demands for water compete with the need to maintain streamflow for biological systems. Human water demand peaks during summer and early fall when streams are experiencing their lowest flows of the year. In the San Lorenzo River, the disparity in timing that exists between the seasonal availability of water and the demand for its use has resulted in a complicated system of water storage systems, groundwater pumping, winter and summer diversion systems and cross-basin transport of water. Multiple agencies, including the District, distribute water to residents in the San Lorenzo Valley and other local communities (Alley et al., 2004a).

Streamflow is a limiting factor to salmonid populations. Streamflow is the primary element that defines total available habitat for salmonids, and to a large extent, determines habitat quality for juveniles related to habitat depth and food supply, with other limiting factors also affecting habitat quality and the ability to reach available habitat. For more information about the impacts of water diversions and groundwater pumping on salmonids, refer to Appendix A: Fisheries.

In the San Lorenzo River, the disparity in timing that exists between the seasonal availability of water and the human demand for its use has resulted in a complicated system of water storage systems, groundwater pumping, winter and summer diversion systems and cross-basin transport of water. Multiple agencies distribute water to residents in the San Lorenzo Valley and other local communities. The largest agencies are the City of Santa Cruz Water Department, California American (formerly Citizen's Utilities), the San Lorenzo Valley Water District, and the Scotts Valley Water District.

4.6.4.a Water diversions

The primary water diverter on the lower mainstem of the river is the City of Santa Cruz Water Department, which has three primary facilities that divert and store water. The systems include Loch Lomond Reservoir on Newell Creek, the Felton Diversion Dam a half-mile downstream of the Zayante Creek confluence, and the Tait Street Diversion near Santa Cruz, which includes streamside wells that can be used in place of diversion. Significant water diversions are also taken from tributaries to the San Lorenzo River. The largest diverter is the San Lorenzo Valley Water District, with its diversions from tributaries to Boulder Creek and Clear Creek. The

County's San Lorenzo River Watershed Plan documented impacts of municipal water use on fishery habitat as early as 1979 (County of Santa Cruz, 1979).

Additionally, the District diversion from Fall Creek draws water to serve the community of Felton. The Felton water system was operated by California American Water Company until its acquisition by SLVWD in 2008. The Lompico County Water District also diverts from Lompico Creek. For more information, see "Chapter 2: Overview of the District's Land & Water."

The District has not fully analyzed the potential impacts of its water diversions at different times of the year on aquatic habitat and fisheries in its own streams and on the larger San Lorenzo River.

There are also more than 130 individual private water diversions in the watershed. The potential impact of these is estimated to be relatively small (0.2-0.4 cfs.), given the small size of the properties and limited amount of irrigation where water is used (Ricker, 1979).

Each of these diversions collectively has an impact not only on local tributary stream conditions but has a cumulative impact on the middle and lower mainstem of the San Lorenzo River.

4.6.4.b Groundwater pumping

Another significant source of flow reduction that is much more difficult to monitor and quantify than diversions from creeks is groundwater well pumping. Groundwater basins support springs and seeps that are a significant source of summer baseflow for the San Lorenzo River and its tributaries, especially in Bean, Zayante, and Carbonera Creeks. Much of the pumping of significant groundwater resources occurs in the Zayante and Bean Creek watersheds by the Scotts Valley Water District and the San Lorenzo Valley Water District. These groundwater basins are formed in the highly permeable, porous Santa Margarita sandstone formation and underlying Lompico formation.

Water diversion and pumping designed to maximize spring and summer streamflows would considerably benefit the production of larger juvenile salmonids in the mainstem river and the production of young juveniles and yearlings in tributary streams. This would, in turn, increase the number of returning adult steelhead and coho salmon as the spawning population.

4.6.5 Mining and quarries

Open pit mining is probably the most severe form of habitat removal and degradation. Entire mountains may be removed by mining. The geology, soils, and water table are also removed or altered by mining. Natural contours are removed and steep cliffs or cut banks are left at the property line of the quarry. Mines can be cut or restored to more natural contours (Spence et al., 1996).

Much of the already extremely rare and fragmented sandhills and sand parkland ecosystems have been removed and fragmented by sand pit mines, including approximately 1,200 acres of Ponderosa Pine parkland (San Lorenzo Valley Water District, 1985). According to the Sandhills Conservation and Management Plan:

> Since its inception during the first half of the 20th century, sand quarrying in the sandhills has occurred in six separate quarries. Three of these operations were completed decades ago, prior to the inaction of the Surface Mining Reclamation Act (SMARA) in 1975, and thus were not revegetated. They are the Scotts Valley Quarry (on Scotts Valley Drive), the Old Geyer Quarry (at the end of Geyer Road near Scotts

Valley), and the old Kaiser quarry that is part of the present day Olympia Wellfield managed by the San Lorenzo Valley Water District (McGraw, 2004).

Remaining sandhills and sand parkland are unmined on the "south ridge," in Quail Hollow County Park, within District lands, and a few other privately owned areas.

Quarries have been a source of sediment in water within the watershed for many decades. In response to Department of Fish and Game complaints about sand plant operations on Zayante and Bean Creeks releasing silt that adversely affected fisheries, the Department of Water Resources conducted a water quality study in 1957 (California Department of Water Resources, 1958). The purpose of the study was to provide data analysis for the CCRWQCB, then known as the Central Coast Water Pollution Control Board, to evaluate waste discharge conditions, and establish regulatory policies. It was common practice at the time for quarry operations to clean mined sand with creek water, and then store the sediment-laden by-product in settling ponds. At periods of high streamflow, they would open the gates on the ponds and flush them out into the creek, claiming no adverse impacts to water quality. The study was inconclusive, due to extremely high storm flows during the sampling period, and because sand plant operators prematurely released sediment, thereby precluding control sampling. However, even under these conditions, the scientists noted "a very noticeable difference in the color of the stream, above and below the discharge" (California Department of Water Resources, 1958).

Some quarries have had on going problems of excess sediment entering the streams from poor management, failure to follow rules or large storms compromising control efforts. Quarries are sources of excess sediment to streams, so prudent control measures, management and monitoring is necessary including agency monitoring and enforcement. Quarry operations in the Bean and Zayante Creeks subwatersheds, and in Gold Gulch, have substantially reduced sediment releases, since adoption of the original County Watershed Management Plan in 1979 (Hecht and Kittleson, 1998). Felton Quarry has been a source of dissolved minerals such as sulfate, iron, and manganese in the past (Camp, Dresser & McKee, 1996).

The Quail Hollow sand quarry is active. Both Hansen and Olympia quarries have closed and are implementing their reclamation plans. However, according to McGraw (2004), a plan was developed to restore sand parkland following mining at the Olympia Quarry, but the success criteria used to define restoration were not attained. As a result of this failure, it is generally considered impossible to recreate sandhills habitat (B. Davilla, pers. comm. 2002).

4.6.6 Recreational use

Off-road vehicle use and equestrian use have had a noticeable impact on the San Lorenzo River watershed. In sensitive habitats, such as District-owned Olympia watershed lands and conservation reserve areas within the Quail Hollow Quarry, recreational uses pose a significant risk to sensitive species. Due to the fragility and rarity of the sandhills species and communities, the impacts of recreation are disproportionately large in the sandhills relative to other systems in the region. Recreational use in undeveloped sandhills habitat results in plant cover removal, erosion, and threats to sensitive species populations in many sites (McGraw, 2004).

The District has not fully documented the impacts of recreational use on District lands on biotic resources.

Recreation impacts sandhills communities and species in various ways, depending on the magnitude (intensity and severity), areal extent, shape, and return interval of use (McGraw, 2004). Both the intensity of the recreation (the strength of the force) and the severity of the disturbance, (the degree to which biomass is removed) contribute to the magnitude of the disturbance. McGraw (2004) observed that on trails used for different types of recreation, the magnitude of disturbance increased with different types of recreation. Walking caused the least disturbance, followed equally by horse riding and mountain biking, and OHV riding causing the most disturbance.

The area of use influences disturbance impacts. Non-trail recreational use in which patches of habitat are transformed into arenas for gatherings, paintball wars, shooting, and OHV riding result in large areas being denuded. While wildlife and pedestrian trails are rarely incised, trails used by equestrians, mountain bikes, and OHVs are frequently incised where they occur in sloped areas (S. Singer, pers. comm. 2004, as quoted in McGraw, 2004).

The shape of the disturbed area, specifically the perimeter to area ratio, influences recreation impacts on habitat by affecting recolonization following disturbance. Arenas have a low perimeter to area ratio compared to trails, and wider trails characteristic of higher intensity uses (equestrians, OHVs) have greater perimeter to area ratios than narrow trails. This ratio influences the rate of recolonization following disturbance by determining the disturbance plants (and then animals) must disperse from adjacent, undisturbed habitat (McGraw, 2004).

Finally, the time between successive recreational uses determines the amount of time the system has to recover between disturbances, and so greatly influences the impact of recreation. If the time between trampling events is long enough, plants can recover and soil crusts can reform, such that the next disturbance will not further impact site conditions. However, because of the fragile nature of sandhills soils and plants, even low frequency recreation denudes trails (McGraw, 2004).

4.6.7 Chemicals and pesticides

Because sandhills soils are so porous, aquifers beneath these soils are especially vulnerable to chemicals, pesticides, and leachate from septic tanks, all of which have the potential to readily enter the aquifer and contaminate the water supply. Thus, use of herbicides to control and eradicate exotic plants in the sandhills must be carefully controlled (McGraw, 2004).

4.6.8 Exotic species

Urbanization, resource extraction, land disturbance and development of the San Lorenzo River watershed have introduced and aided in the proliferation of non-native plants and animals. Non-native species are detrimental to ecosystem functions and biodiversity.

The District has not surveyed and mapped exotic species on District lands.

4.6.8.a Exotic mammals

Exotic animals impact ecosystem functions. Of all the exotic species in the San Lorenzo River watershed, the feral pig is of particular concern, because it causes severe erosion and sedimentation. Feral pigs disturb the riparian zone as they dig and root. This activity leads to bank failure, slumping, and other geologic hazards within riparian areas. Feral pigs also transmit waterborne pathogens such as Giardia cysts and Cryptosproridium oocysts (Camp, Dresser & McKee, 1996). Feral pigs damage sensitive native plants and invertebrates. They reproduce quickly and are very hard to eradicate. State Parks is working to control feral pigs on lands owned by the department. While regional eradication is perhaps possible and certainly desirable, this is not the goal of this program (Hyland, 2007).

Feral pigs are known to inhabit the District's watershed lands, especially around Foreman Creek. The extent of the damage they have caused has not been estimated at this time.

Feral dogs and cats, which breed in the wild, may hunt and kill native species. Escaped pets of all types may reproduce and could also negatively affect the ecosystem.

4.6.8.b Exotic aquatic animal species

Crayfish are an invasive exotic species to the San Lorenzo River watershed. Crayfish were shipped in large batches to the California Fish and Game Commission Hatchery in Brookdale in 1912 in order to determine their negative effects upon young steelhead; and were later released into the San Lorenzo River (Cohen and Carlton, 1995). Non-native crayfish have changed the instream environment for native species such as steelhead, coho salmon and frogs. Some areas of the San Lorenzo River have large populations of non-native crayfish, which compete with steelhead for cover and food and may prey upon juvenile steelhead.

Bullfrogs, during their longer and larger tadpole stage, may prey upon native red-legged frog tadpoles. Adult bullfrogs prey on red-legged frogs at any life stage. Bullfrogs may also prey upon juvenile steelhead. Bullfrogs quickly proliferate, and are difficult to eradicate. Quantifying the effect of introduced bullfrogs on redlegged frogs is difficult. Undoubtedly, their role varies on a site-by-site basis. Doubledee et al. (2003) have developed a model to quantitatively measure bullfrog predation on California red-legged frogs. The model can potentially be used to assess individual sites. Bullfrogs are abundant in ponds at Roaring Camp, and have been observed as adults in Zayante Creek adjacent to the Trout Farm pond. Bullfrog tadpoles were captured in middle Boulder Creek in 2006 (Alley, 2006 pers. communication).

4.6.8.c Exotic invasive plants

Exotic (non-native) invasive species tend to take over and reduce plant diversity and spatial complexity.

Three local experts have documented non-native "exotic" plants in Santa Cruz County in a booklet entitled "A Plague of Plants: Controlling Invasive Plants in Santa Cruz County" (Moore, Hyland, and Morgan, 1998). Randal Morgan is a local taxonomic expert. Tim Hyland has worked in local resource management for many years. Ken Moore has led the Wildlands Restoration Team, which works with volunteers to eradicate non-native plants on public lands in Santa Cruz County since 1990. The authors describe the impacts of exotic plant species to the region:

> An exotic plant is simply a species that has been introduced into an environment different from that in which it evolved. While not all exotics are a problem, some are invasive; these are capable of displacing other species, thereby leading to their demise. Having left behind the predators and competitors that kept them in balance with other species at home, invasive exotics can proliferate unchecked, like a cancer on the land. The most invasive exotics can choke out native flora and provide no habitat value for

native fauna. They can form impenetrable thickets or mats, shading out the seedlings of native plants, competing for nutrients and water, or even fundamentally changing the soil to favor their kind. Most insects, birds, and other animals have adapted to use relatively few plant species for food, shelter, or nest sites. A loss of their preferred species can result in their decline or even extinction. If a sufficient number of species are eliminated, or even a few "keystone" species, the whole ecosystem can collapse. Some were introduced deliberately for their ornamental beauty, some came as contaminants in animal feed or as stowaways on stock animals' hides or hooves. Others were introduced speculatively for their supposed value as timber, or for erosion control. Many were brought here because of their ability to grow quickly, giving them yet another powerful advantage in out competing and forcing out native species.

Table 4.8 lists common invasive exotic plants found in the Santa Cruz Mountains.

Table 4.8 Common Santa Cruz County invasive exotic* plants

Plant type	Common name	Species
Herbaceous		
	Cape ivy	*Dilaireia odorata*
	Iceplant	*Carpobrotus edulis*
	English ivy	*Hedera helix*
	Algerian ivy	*Hedera canariensis*
	Bull thistle	*Cirsium vulgare*
	Italian thistle	*Carduus pycnocephalus*
	Yellow star thistle	*Centaurea solstitialis*
	Periwinkle	*Vinca major*
	Poison hemlock	*Conium maculatum*
	Wild fennel	*Foeniculum vulgare*
	Himalayan blackberry	*Rubus procerus discolor*
	Cocklebur	*Xanthium sp.*
	Forget-me-not	*Myosotis latifolia*
Grasses		
	Bermuda grass	*Cynodon dactylon*
	European dune grass	*Ammophila arenaria*
	Giant reed grass	*Arundo donax*
	Kikuyu grass	*Pennisetum clandestinum*
	Harding grass	*Phalaris aquatica*
	Common sheep sorrel	*Rumex acetosella*
	Common velvet grass	*Holcus lanatus*
	Hairy cat's ear	*Hypochaeris radicata*
	Big quakinggrass	*Briza maxima*
	Silver hairgrass	*Aira caryophyllea*
	Rat-tail fescue	*Vulpia myuros*
	Brome fescue	*Vulpia bromoides*
	Smooth cat's ear	*Hypochaeris glabra*
	Ripgut brome	*Bromus diandrus*
Trees		
	Monterey pine**	*Pinus radiata (non-native variety)*
	Eucalyptus, Tasmanian bluegum	*Eucalyptus globules*
	Acacia**	*Acacia spp*
Shrubs and brush plants		
	French, Spanish, Portuguese and Scotch broom	*Genista monspessulana and spp.*
	Pampas grass**	*Cortaderia jubata and Cortaderia selloana*

* Not native to this area; most not native to the United States.
** Poses heightened fire risk
Source: Moore et al., 2002; McGraw, 2004

Exotic plants of the redwood forest

During forest restoration efforts, exotic species are removed to restore healthy riparian function and native species diversity. Common invasive tree species include acacia and blue gum eucalyptus. Common herbaceous plants and shrubs include periwinkle (*Vinca major*), English ivy, bull thistle, Himalayan blackberry, poison hemlock, forget-me-not, and French broom. Most of these plants are present to some extent on District-owned lands.

Chaparral invasive plants

The most common invasive plants in the chaparral plant communities are French broom and pampas grass.

Exotic plants of the riparian woodlands

During riparian restoration efforts, exotic species are removed to restore health riparian function and native species diversity. Alley et al. (2004) documented invasive plant species along streams in Santa Cruz County. Common invasive, non-native tree species include acacia, Monterey pine, and blue gum eucalyptus. Common invasive herbaceous plants and shrubs include French broom, pampas grass, cape ivy (also known as German ivy) (*Senecio mikanoides*), English ivy, Himalayan blackberry (*Rubus discolor)*, nasturtium (*Nasturtium officinalis*), honeysuckle (*Lonicera* sp.), morning glory, giant reed grass (*Arundo donax*), cotoneaster (*Cotoneaster spp.),* and periwinkle.

Exotic plants of the sandhills and sand parklands

As in other sensitive plant communities, exotic plant species in the sandhills threaten native plants directly, through their competition, and indirectly, through their abilities to alter ecosystem structure and function (McGraw, 2004).

European annual grasses and forbs are the most abundant exotic plant species in the sandhills. European annuals are widespread and abundant in sand parkland, where predominantly open canopy conditions are conducive to their growth (McGraw 2004).

In sand parkland, the hotter, drier south-facing slopes are dominated by European *Vulpia* species (*V. myuros* and *V. bromoides*)*, Hypochaeris glabra,* and to a lesser extent *Bromus diandrus.* While *H. glabra* is also abundant on north slopes, another diminutive grass, *Aira caryophyllea* dominates the cooler slopes. *Briza maxima* prefers to grow underneath pines and sometimes underneath oaks. The litter from both types of trees greatly reduces the abundance of both *V. bromoides, V. myuros,* and *H. glabra* (McGraw, 2004).

Many aggressive European perennial grasses and forbs found throughout Santa Cruz County have yet to invade the sandhills, suggesting that the sandhills may indeed have some abiotic resistance to invasion due to a combination of hot dry summers and low nutrient conditions. Two exceptions to this trend are *Hypochaeris radicata* and *Rumex acetosella*, which are found in the more mesic microsites in sand parkland. While *H. radicata* is relatively rare, *R. acetosella* is patchily very abundant under trees and on north slopes in sand parkland (McGraw, 2004).

A third noteworthy exception to the trend is the recent invasion of *Holcus lanatus* into the sandhills. Well known for its ability to invade and quickly dominate wet grasslands and meadows, this European perennial grass is rapidly becoming one of the most abundant exotic plants in mesic grasslands communities in central California, including Santa Cruz County (McGraw, 2004).

Aggressive shrubs and trees as well as the shrub-sized pampas grass (*Cortaderia jubata;* have invaded many sandhills sites. Large exotics including *Acacia dealbata, Eucalyptus* sp., *Cytisus multiflorus*, *C. scoparius,* and *Genista monspessulana,* are often found along roads and have become established on the perimeter of many sandhills habitat patches. *Acacia dealbata* became established and abundant at the old quarry of the Olympia Wellfield. Also in the Fabaceae, this tree not only has a persistent seedbank, but readily 'stump sprouts' such that simply cutting the tree at the trunk does not kill the plant, though techniques for eradicating this aggressive invader are being developed (McGraw, 2004).

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